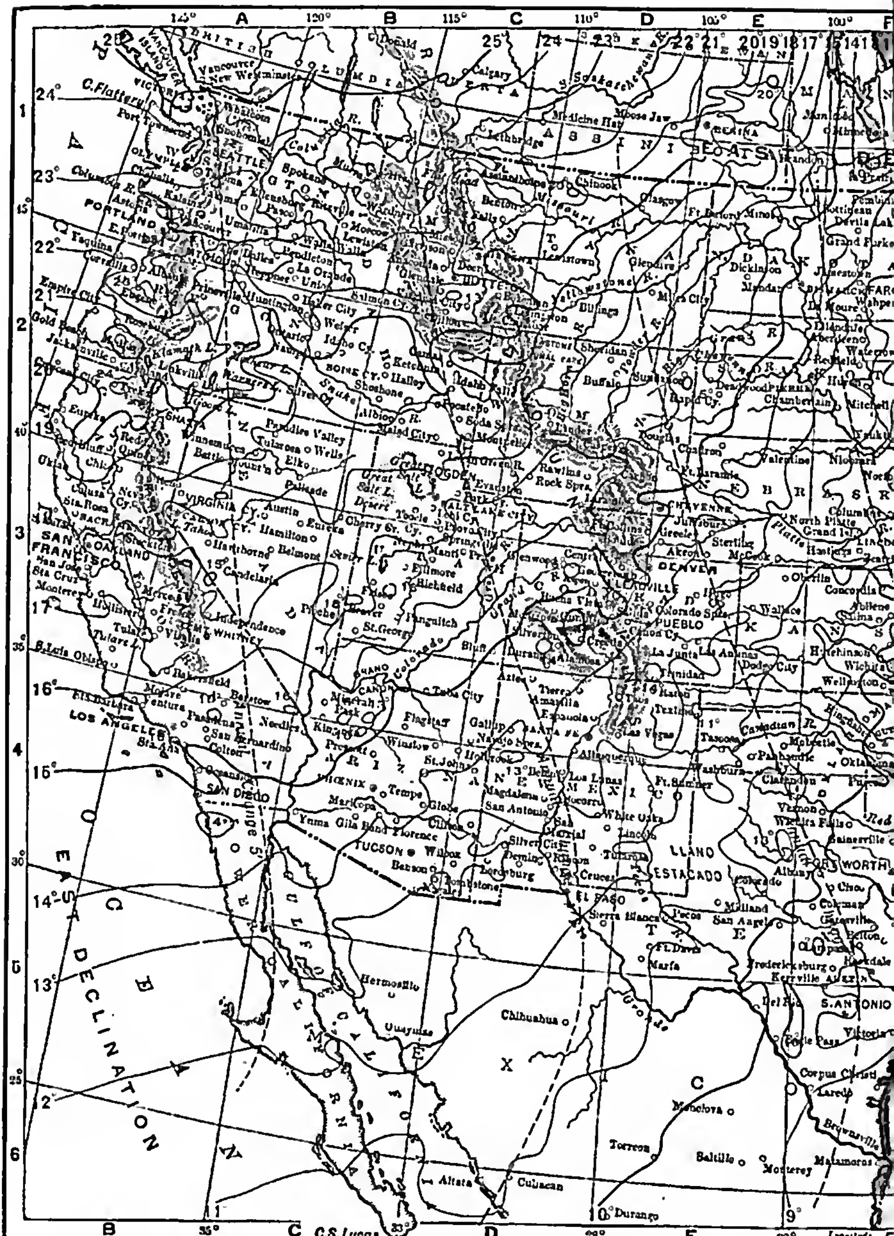

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ELEMENTS

OF

PLANE SURVEYING

(INCLUDING LEVELING)

BY

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REVISED

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PREFACE

The primary object of this work is to give a brief treatise on Plane Surveying, adapted for a short course in colleges, or as a preparatory course in technological institutions. It has been the aim of the author to make clear points that, in his fifteen years' experience, both in the class-room and the field, he has found troublesome to beginners.

In dealing with fundamental principles and operations he has endeavored to answer "simple questions that confound." In carrying this idea out, he has put into the book a few things that he has looked for in vain in existing text-books. The work is brief, and yet is not an outline for a lecture course. On the contrary, it is a book that might be studied privately, or be used by a teacher of but little practical experience. While the work is intended primarily as a text, in its preparation the author has kept in view the possibility of its falling into the hands of county surveyors who may not have had the advantages of a collegiate course.

While the work is elementary, it is believed that it will be found to be scientific, and that the user of the book will not learn anything that he will have to unlearn in more advanced study of surveying or engineering.

Especial attention is called to the following points:

1. Careful description of instruments and their adjustments.
2. The explicit statement of the methods of making a re-survey, in accordance with the different data to be had.
3. The discussion of the declination of the needle, and the excellent isogonic chart at the beginning of the book.
4. The simple methods of obtaining a true meridian line.
5. Suggestive forms for field notes and for purposes of reduction.
6. Many illustrative examples.
7. The clear and complete set of tables.

As the advantages of stadia work are becoming more and more recognized, the fundamental proofs of the theory are given together

with forms for the field notes. In the closing chapter plane leveling is treated in a manner and scope sufficient, it is thought, for the needs of the general surveyor.

In the preparation of the book the standard American works have been consulted.

The author takes this opportunity of thanking Professor Webster Wells for his courtesy in allowing him to reproduce his excellent six-place logarithmic tables and his table of the natural trigonometric functions, which are given here as Tables XVII, XVIII, and XIX, respectively. He acknowledges his indebtedness to the U. S. Coast and Geodetic Survey for courtesies extended through Superintendent O. H. Tittman.

He desires also to acknowledge his indebtedness to the following instrument-makers for use of their cuts or diagrams: Messrs. W. & L. E. Gurley, Troy, N.Y.; George N. Saegmuller, Washington, D.C.; Young & Sons, Philadelphia; Brown & Sharpe Mfg. Co., Providence, R. I.; and Eugene Dietzgen Co., Chicago.

SAMUEL M. BARTON.

REVISED EDITION

In making this revision, the Tables giving the position of Polaris, etc., have been brought up to date; some minor changes have been made in the chapter on the Declination of the Needle; and a new isogonic map, compiled for the year 1910, has been put in the place of one for an earlier date. To make the matter on adjustments somewhat clearer and more in accordance with practice, two new pages have been added.

The author takes this opportunity to thank Professor B. L. Coulson for helpful suggestions.

S. M. B.

Sewanee, Tennessee,
May, 1913.

ANALYTICAL TABLE OF CONTENTS

[The numbers refer to articles]

INTRODUCTION

CHAPTER I

INSTRUMENTS—THEIR USE AND ADJUSTMENTS

CHAPTER II

CHAIN SURVEYING

CHAPTER. III

COMPASS SURVEYING

I. Field Operations — Original Surveys and Re-surveys

II. The Declination of the Needle

III. The Determination of a True Meridian Line

CHAPTER IV

COMPUTATION OF AREAS

SUPPLYING OMISSIONS

CHAPTER V

TRANSIT SURVEYING

I. Field Work and Computation of Areas

II. Laying out and Dividing Land

ELEMENTS OF PLANE SURVEYING

PLANE SURVEYING

INTRODUCTION

1. Surveying is the art of making such measurements as will determine the relative positions of points on the earth's surface, both as to their distances, in a horizontal plane, from certain fixed reference lines (that is, their geographical position) and their distances above, or below, a certain datum plane. It will be observed that the first determination fixes the vertical line through the point, the second giving its exact position in that vertical line.*

2. Surveying has for its object the determination of the lengths and directions of lines on the earth's surface, the dividing and subdividing of tracts of land, the computation of areas and volumes, and the making of maps or plots to represent graphically portions of the earth's surface.

3. In *plane surveying*, the surface of the earth (as given by the sea, for instance) is considered as a plane, the curvative being neglected.

4. In *geodetic surveying*, or *geodesy*, the curvative of the earth is taken into account, and this must be done in extensive surveys.

THE EARTH

The few astronomical definitions here given will be followed by others as the student has occasion to use them.

5. The *axis of the earth* is an imaginary line about which the earth rotates once in every 24 † hours.

* The determination of the horizontal distances is commonly spoken of as plane surveying, while the determination of the vertical distances is called *leveling*.

† See Art. 13.

6. The *poles* are the extremities of the axis, or the points where the axis meets the surface.

NOTE. — The earth is not a perfect sphere, but is what is called an *oblate spheroid*, being flattened at the poles. According to "Clarke's Spheroid of 1866" (which is adopted by the United States Coast and Geodetic Survey) the dimensions of the earth are:

Equatorial radius	= 6,378,206.4 metres,
	= 3,963.307 miles.
Polar radius	= 6,356,583.8 metres,
	= 3,949.871 miles.

7. The *equator* is that great circle of the earth which is midway between the poles. Its plane is perpendicular to the axis of the earth.

8. *Meridians* are great circles passing through the poles perpendicular to the equator.

9. Latitude and Longitude. — In geography, any place on the earth's surface is definitely known if its distance from the equator (that is, its *latitude*) and its distance from a certain reference meridian (that is, its *longitude*) are given. The English reckon longitude from the meridian through the Royal Observatory at Greenwich, while in the United States longitude is reckoned from the Washington meridian, or often from the Greenwich meridian.

Latitude is *north* or *south* according as the place is north or south of the equator.

Longitude is *east* or *west* according as the place is east or west of the reference meridian.

Latitude is given in degrees, minutes, and seconds; longitude, in degrees, minutes, and seconds, or hours, minutes, and seconds, one hour corresponding to 15°.

10. A *vertical line* is the direction of gravity, as indicated by a plumb-line, at any point on the earth's surface.

A *horizontal line* is a line perpendicular to a vertical line.

11. A *vertical plane* is any plane that contains a vertical line.

A *horizontal plane* is a plane perpendicular to a vertical line.

12. A *vertical angle* is an angle whose sides lie in a vertical plane.

A *horizontal angle* is an angle whose sides lie in a horizontal plane.

An *angle of elevation* is a vertical angle, the *lower* side of which is horizontal, the other oblique.

An *angle of depression* is a vertical angle, the *upper* side of which is horizontal, the other oblique.

THE CELESTIAL SPHERE *

13. The Celestial Sphere. — An observer on the earth is seemingly at the centre of a huge sphere, one half of which is the sky above him. This sphere, on the surface of which all the heavenly bodies appear to be, is called the *celestial sphere.* Owing to the rotation of the earth from west to east, this sphere, with its countless stars, apparently turns completely around from east to west once in about 24 hours (really in 23 hr. 56 min. 4.1 sec. of ordinary time).

14. The *poles of the celestial sphere* are the points where the axis of the earth produced pierces the celestial sphere.

15. The *zenith* is that point of the celestial sphere directly over the head of the observer; the *nadir* is the opposite point directly under his feet.

16. The *meridian* is the great circle passing through the pole and the zenith.

17. The *horizon* is a great circle which is everywhere 90° from the zenith.

18. *Vertical circles* are great circles passing through the zenith and perpendicular to the horizon.

19. The *altitude* of a star † is its distance from the horizon measured on the vertical circle through the star. The *zenith distance* is the complement of the altitude.

20. The *azimuth* is the angle at the zenith between the meridian and the vertical circle which passes through the star.

Note. — If a star's altitude and azimuth are given, its position in the heavens is known.

21. The *celestial equator* is the intersection of the plane of the earth's equator with the celestial sphere.

22. *Hour-circles* are great circles passing through the north and south poles of the heavens and perpendicular to the celestial equator.

23. The North Pole. — In the apparent diurnal revolution of the stars, those near the north pole never set to an observer in the

* The student will have occasion to use these definitions when he reaches the study of the theory of the solar compass, and in the chapter on the determination of a true meridian line.

† Any heavenly body.

northern hemisphere, but revolve in their so-called *diurnal circles* once a day * (see Art. 13). The north pole is conveniently marked by the pole-star (*Polaris*), which is now only about $1\frac{1}{4}°$ from the pole. The pole-star may easily be found from its being nearly in a line with the so-called "pointers," two stars in the "dipper" (of the constellation of Ursa Major) (see Fig. 49).

The pole is very nearly on a line joining Polaris with the star ζ Ursa Major, at the bend of the handle of the "dipper." This fact furnishes one method of getting a meridian line (see Art. 146).

24. Culmination. — The circumpolar stars pass the meridian *twice* in 24 hours (see Art. 13), once *above* and once *below* the pole. These meridian passages are called respectively the *upper* and *lower culminations.*

25. The Ecliptic. — The ecliptic is the path on the celestial sphere described by the sun in its apparent eastward motion among the stars that causes it to complete the circuit of the heavens once a year. The *ecliptic* is a great circle inclined to the equator at an angle of about $23\frac{1}{2}°$. The *poles of the ecliptic* are obviously 90° distant from the ecliptic.

26. The Equinoxes. — The *equinoctial points* are the two points in which the ecliptic intersects the celestial equator.

The *vernal equinox* is that one of these points which the sun passes in the spring, and the *autumnal equinox* is that passed in the autumn.

27. The *declination of a star* is its distance north or south of the celestial equator measured on an hour-circle. Its *north polar distance* is the complement of its declination.

28. The *right ascension of a star* is its distance measured on the celestial equator from the vernal equinox to that hour-circle which passes through the star.

29. The *hour-angle* is the angle between the meridian of the observer's place and the star's hour-circle.

30. The position of a star in the celestial sphere is determined if its right ascension and declination (or north polar distance) are given; or if its hour-angle and declination (or north polar distance) are given.

* Such stars are called *circumpolar.*

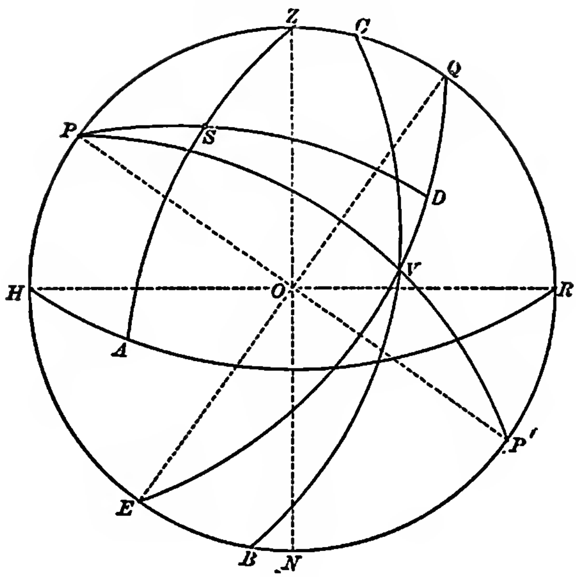


FIG. 1

31. Figure 1 is supposed to represent the celestial sphere, the full circle being the meridian of the observer, and S being the position of a star, or other heavenly body. Then:

$HPZRN$ = meridian,	P' = south pole,
Z = zenith,	V = vernal equinox,
N = nadir,	SA = altitude of the star,
HAR = the horizon,	RA = azimuth of the star,
EQ = the equator,	ZS = zenith distance of the star,
BC = the ecliptic,	SD = declination of the star,
PV, PD = hour-circles,	PS = north polar distance,
ZA = a vertical circle,	VD = right ascension of the star,
P = north pole,	ZPS = hour-angle.

CHAPTER I

INSTRUMENTS—THEIR USE AND ADJUSTMENTS

32. Gunter's Chain. — Gunter's chain, so called after the inventor, is 66 ft. (4 rd.) in length, and is divided into 100 links, each link being 7.92 in. long.*

A "link" consists of a straight piece (or link) of wire bent into rings at the ends, together with one or one and a half rings at each end according as there are two or three rings connecting the wires. The object of the connecting rings is to give flexibility to the chain. The best chains are made of steel wire and have a brass handle at the ends. Every tenth link is marked by a brass tag, the number of points on the tag, from each end to the centre, indicating the number of tenths from the end, the middle tag being oval. The "length" of the chain includes the handles. Gunter's chain is used only in obtaining the area of land when the acre is the unit. The fact that 10 square chains make an acre renders it a very convenient linear unit, though we often find distances expressed in terms of the smaller unit, the rod (or pole). In rough or mountainous country it is customary to use a half-chain, made just like Gunter's, except that it is 33 ft. long and has only 50 "links."

33. The Engineer's Chain is 100 ft. long and is divided into 100 "links," each 1 ft. long. It is used in surveying railroads, highways, etc., and is now often used instead of Gunter's chain in ordinary land surveys.

34. Tapes. — The *steel tape*, which is made in various lengths and is graduated into feet and inches, or feet and tenths, consists of a continuous piece of steel, about a quarter of an inch wide and $\frac{1}{200}$ of an inch thick. Instrument manufacturers make the tape in lengths ranging from 25 ft. up to 1000 ft., those in common use being 50 ft. or 100 ft. The longer tapes are used in bridge work or other special surveys. The steel tape has for many purposes taken the place of the engineer's chain. The *linen tape* is useful for domestic purposes,

* See Table XI, page 147.

fencing, etc.; but owing to the ease with which it stretches and wears, it is too unreliable for the surveyor's use.

Tapes sold under the name of *metallic tapes* are made of linen with fine brass wires woven throughout their lengths. While much better than the ordinary linen tape, they fall far short of steel tapes in efficiency and reliability.

35. Standards. — To insure accuracy of measurement, all tapes and chains should be compared with the United States standard. For a small fee the United States Coast and Geodetic Survey, Washington, D.C., will test any chain or tape sent to them. The surveyor is advised to lay off and carefully mark the length of a chain that has been so tested on a curbing, or on the ground, marking the ends by a line cut in a rock that has been securely bedded in the ground. He has then a ready means of testing his chain from time to time, a precaution which should be taken frequently.

The ordinary Gunter's chain has 600 wearing surfaces. If each of these surfaces wears .005 of an inch, the chain will be lengthened *three* inches, so that in running a line a half a mile long an error of 10 ft. will be made. The steel tape, while not so subject to change as the chain, is variable, owing to its contraction and expansion caused by changes in temperature. It is of *standard* length only for a given temperature (usually taken at 62° F.).

It is beyond the scope of this work to describe instruments for precise measurement, or to explain the methods employed when great precision is required, as, for instance, in establishing a United States Coast and Geodetic Survey base line.

36. Comparison of the Chain and Tape. — Some of the defects of the chain are: the number of wearing surfaces and consequent liability to change in length; its weight, preventing its being kept horizontal unless resting on the ground; when used in wet places the numerous rings are apt to become clogged with mud and grass; the links are liable to be bent, and when straightened again they are always longer than before being bent.

Among the advantages of the chain over the tape may be mentioned its durability and, owing to its flexibility and strength, the ease with which it may be carried through brush and over rough ground. In rough country, for purposes not requiring great accuracy, the chain is much more satisfactory than the tape.

The defects of the tape are its liability to break and the difficulty of repairing it. It is apt to rust, and thus the graduations are made

indistinct. In a high wind it is inconvenient to use. As we have seen, it expands and contracts with changes of temperature (though the chain is of course similarly affected).

Notwithstanding these obvious defects, the steel tape (if proper corrections are made for changes of temperature, etc.) is a far more reliable and convenient measuring instrument than the chain, and should always be used in preference to the chain when accuracy is desired.

37. Pins.—For marking chain lengths, iron or steel pins, usually about 14 in. long, and bent in the form of a ring at the top, are used. Eleven is the most convenient number, though some surveyors use ten. They should be made heavier toward the bottom, so that when dropped from the hand they will fall plumb.

38. Range Poles. — To range out a line, at least two poles are required. Range poles are usually of wood, 6 to 8 ft. long, painted in strips alternately red and white, and shod with a pointed iron shoe. An iron pipe is sometimes used, but is objectionable for several reasons. It is heavy, and if bent is hard to get perfectly straight again. When iron poles are used in compass surveying, great care must be taken not to leave them standing in the ground near enough to the instrument to cause a deflection of the needle.

USE OF THE CHAIN (OR TAPE)

39. To measure a Line with a Chain. — All distances should be measured horizontally. This method of measuring is prescribed by law in most states. It is the scientific way, for horizontal measurement is necessary in order to obtain a correct plot or map. What is really measured is the projection of surface lines on a horizontal plane; and the area obtained is the area of the horizontal projection of the surface. Hence the chainmen must keep the chain horizontal by elevating the rear end in going uphill and the front end in going downhill. If the hill is very steep, it may not be possible to elevate the end of the chain enough to keep it horizontal. In this case it is customary to use a part of the chain at a time. Care must be taken to put the elevated end exactly over the pin. The safest way is to use a plumb-line, or a straight rod with a level attached to it.*

* In the absence of a plumb-line or rod with level, the pin (see Art. 37) should be held loosely by the ring and, when steady, dropped, thus determining the point under the end of the chain.

The following is the usual order of procedure:

Where eleven pins are used, the leader (front chainman) takes ten pins, leaving one with the follower (back chainman) at the beginning of the course. After the leader has the chain stretched out approximately along the course, the follower directs him by motioning with his hand, or by calling "right," "left," until he puts him on a line with a range pole at the end of the course, or at some convenient place on the course. The leader then pulls the chain taut, being careful to keep it horizontal, and puts a pin on the line exactly at the end of the chain. The best way to do this is to take one pin in the (right) hand that grasps the handle of the chain, and, standing to one side so as not to obstruct the view, let the follower line him with the pole. The leader, being in a stooping position, can readily stretch the chain by placing his right elbow on the inside of his right knee, using the latter as a fulcrum. When the follower calls "stick," he firmly presses the pin into the ground and says "stuck." The follower should in no case take his pin up till the leader signifies that he is ready by calling "stuck" (or "down"). When he has done this, the follower takes up the pin that has been left with him, and they both move on. The follower should warn the leader in some way that he is nearing another pin, and not stop him with a sudden and violent jerk on the chain. The follower holds the end of the chain at the pin, and as before "lines" the leader, calling "stick" when he is in the right position, and again, when the leader has stretched the chain and placed his pin, he calls "stuck," and the follower takes up his pin; they move on, and repeat the process until the end of the course is reached. Should the distance exceed ten chains, when the leader has stuck his last pin, he calls "out," and the follower, dropping his end of the chain, walks up to the leader and gives him all the pins in his hand (ten in number). To avoid mistakes, both the leader and the follower should count the pins so as to make sure that ten have changed hands. Notice that the eleventh pin is still in the ground and is not counted, and that the distance up to this pin is ten chains. The leader moves forward and the measurement proceeds as before. When ten chains have thus been measured, there is said to be an "out," and the number of *outs* must be carefully kept. To assist the memory, a contrivance called an out-keeper is put on the plate of the compass (see Fig. 2).

At the termination of a course, the end of the chain is held at the terminal stake, and the number of links back to the last pin is

counted. Notice that this last pin, *within less than a full chain of the terminal stake*, is never counted.

NOTE. — Avoid the common mistake of reading from the wrong end of the chain, counting 40 links instead of 60, or of counting on the wrong side of a tag, putting 28 for 32, for example.

40. Too great emphasis cannot be laid upon the importance of careful chaining if the best results are desired. In much work the surveyor must depend upon green hands to "carry" the chain, but he should in such cases give them instruction as to the proper way to handle the chain, and he should in person watch them for a few courses (and every now and then later on) to insure especially, first, that the chain is held taut and horizontal; second, that no gaps or overlaps are allowed when the pin is stuck, an error that is apt to occur on hilly ground; third, that the number of links at the end of the course is properly counted. Some errors are compensating, but, as a rule, the fewer the errors, the more accurate the work.

A *compensating* error is one that is as likely to be plus as minus, such errors tending to balance one another. A *cumulative* error is one that is constantly of the same sign; such errors, instead of tending to annul one another, accumulate as the work progresses. Thus, in chaining, the error in setting the pin is compensating, while an error due to erroneous length of the chain is cumulative.

41. Error in Length of the Chain. — It is evident that if the chain is too long the number expressing the length of the line is too small, or the line is longer than the measurement makes it; and if the chain is too short, the length of the line as found is too great. In either case, x, the true length of the line, is given by the following proportion:

$$\text{Length of standard chain} : \text{length of chain used} = \text{the distance measured} : x.$$

For example, with a chain one link too long the length of a line is 44.32 chains; what is its true length?

Here $1 : 1.01 = 44.32 : x$, or $x = 44.76$ chains.

42. Correction for Area. — As areas of similar figures are proportional to the *squares* of homologous sides, the formula for correcting area is:

$$\text{True area} : \text{computed area} = \text{the square of the length of chain used} : \text{the square of the length of standard chain}.$$

For example, suppose the chain used is one link too long, and the area of a certain field is found by computation to be 544 square chains, what is the value of its true area, S?

Here $S : 544 = (1.01)^2 : 1^2$,

or $S = 554.93$ square chains, true area.

THE SURVEYOR'S COMPASS

43. The Surveyor's Compass, a cut of which is shown below, consists of a plate of metal supporting at each end a standard, or sight-vane, perpendicular to the plane of the plate, the compass-circle, in which the magnetic needle swings, being at the centre of this plate. The compass-circle, which has a glass cover, is graduated to half degrees and is figured from 0° to 90° each way from the

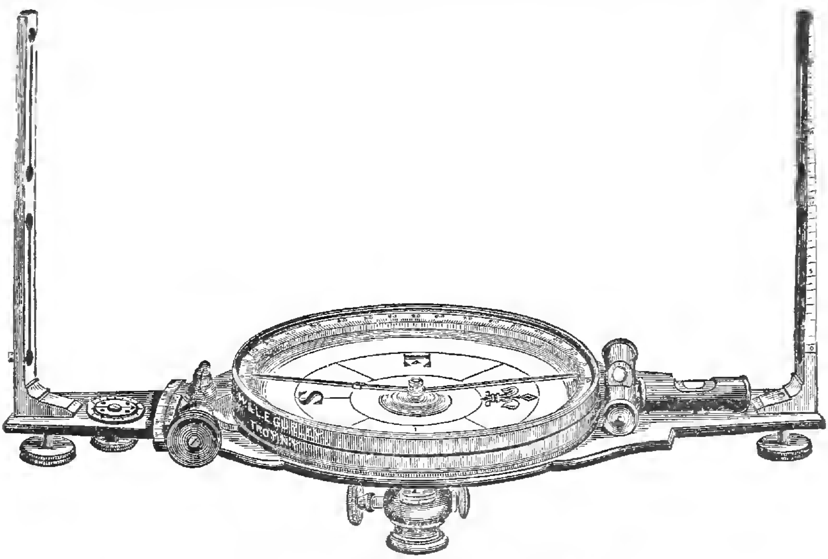


FIG. 2. — Surveyor's Vernier Compass

north and south points of the line of zeros. The four principal points are lettered clockwise* N. W. S. E., instead of N. E. S. W. as on a map, the reason for which will appear later on. The bubbles (or spirit-levels) are placed at right angles to each other, so as to level the plate in all directions. The standards have fine slits cut through nearly their whole length, terminated at intervals by circular apertures, through which the object sighted upon is more readily

* That is, in the direction of the hands of a clock.

found. The *needle* is essentially a magnetized bar of iron so suspended as to swing freely in a horizontal direction and settle in the magnetic meridian. It has an agate or jewelled centre which rests upon a sharp pivot at the centre of the compass-circle. As the precision of the needle depends not only upon its magnetic strength, but upon the ease with which it swings, it is very important to have the pivot sharp and smooth in the beginning and to keep it so.

The north end of the needle is usually designated by a scallop or other mark, and the south end has a small coil of brass wire,* easily

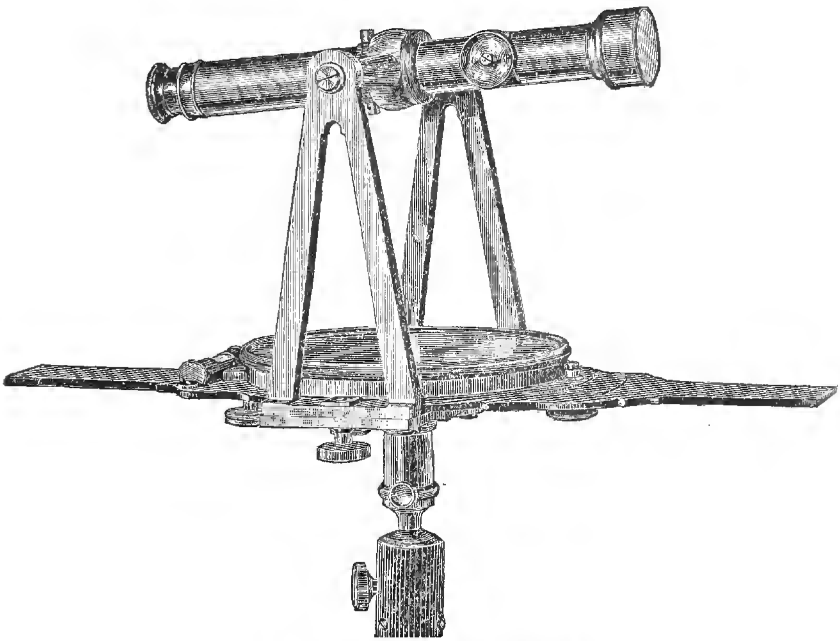


FIG. 3.—Compass with Telescope

moved, so as to bring both ends to the same level. There is a lever worked by a screw, by means of which the needle, when not in use, can be raised up against the glass cover, thus preventing unnecessary wear on the pivot.

The compass is usually fitted to a spindle, which is fastened to the head of the tripod or Jacob's staff by means of a ball-and-socket joint, a device which enables the surveyor to level the instrument very quickly. When a tripod is used, a plumb-bob is suspended immediately under the centre of the spindle.

* To counteract the effect of the "dip" of the needle.

44. In place of the sight-vanes a telescopic sight is often used. There is great advantage in this improvement, as it saves the eyes, and often enables the surveyor to set a pole at a greater distance, and *through brush*, where the pole could not be discovered with the naked eye. A good form * is shown in Fig. 3 on page 12.

45. In the *plain compass*, an instrument used chiefly in the survey of new lines where the variation † of the needle is not required, the compass-box is in the same piece with the main plate.

The *vernier compass*, as illustrated on page 11, has its compass-circle, to which is attached a vernier, ‡ movable about its centre a short distance in either direction, enabling the surveyor to set the zeros of the circle at any required angle with the line of sights. The number of degrees contained in this angle is read by the vernier. The superiority of the vernier over the plain compass consists in its adaptation to retracing the lines of an old survey, furnishing as it does a ready means of setting off the change in declination.

VERNIERS **

46. A *vernier* is a short auxiliary scale, movable by the side of a longer scale called the limb, by means of which subdivisions of the limb may be measured.

A division of the vernier is a little shorter or a little longer than a division of the limb, and it is this small difference that we are enabled to measure.

A vernier is usually constructed by taking a length equal to a given number of spaces on the limb and dividing this length into a number of equal spaces, one more or one less than the number into which the same length on the limb is divided. If the number of spaces on the vernier is *one more* than the number of limb spaces covered, it is called a *direct* vernier; if it is *one less*, a *retrograde* vernier; because in the former case it is read in the direction of the motion, and in the latter case opposite to the motion.

Figure 4 represents a direct vernier. Here the limb is supposed to be divided into feet and tenths of feet, and as shown by the first position of the vernier, *AB*, ten spaces on the vernier correspond to

* Made by Young & Sons of Philadelphia.
† "Change in the declination"; see Art. 135.
‡ See Art. 46.
** Named after the inventor, Pierre Vernier.

nine on the limb. Each space on the vernier is one-tenth less than a space (one-tenth of a foot) on the limb. The difference, then,

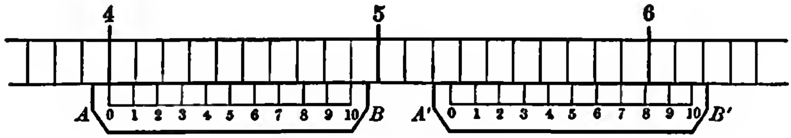


FIG. 4.—Vernier Plate

between a space on the limb and one on the vernier is one-tenth of one-tenth of a foot, or .01 of a foot.

This difference is called the *least count* of the vernier, and is the smallest distance it can measure.

47. To find the *least count* of any vernier, let

s = length of one space on limb,

v = length of one space on vernier,

n = number of spaces on vernier;

then $$ns = nv \pm s.$$

For direct vernier we use the + sign, which gives

$$s - v = \frac{s}{n} = \text{least count.}$$

48. In Fig. 4, with vernier at the position AB, the reading is even 4 ft. Now, if we suppose the vernier to slide along the limb toward the right till the vernier line *1* coincides with the division on the limb next after the 4-ft. mark, the vernier has evidently moved up .01 ft., and the reading is 4.01. If we move the vernier a little farther, so that the line *2* coincides with a line on the limb, the vernier has moved .02 ft. It will be noticed that the feet and tenths are given by the position of the zero-line of the vernier and are read upon the limb-scale, while the hundredths are given by that line of the vernier scale that coincides most nearly with *some* line of the limb-scale. In the second position of the vernier, $A'B'$ in our figure, we see that the seventh line on vernier coincides with one above it, and the zero-line is between 5.2 and 5.3, giving the final reading 5.27.

49. There are many different forms of verniers; a very common form, shown in Fig. 5, is used when the main (limb) scale is graduated

into degrees and half degrees. Here 30 spaces on the vernier correspond to 29 on the limb, and the *least count* is $\frac{1}{30}$ of 30 min. = 1 min., thus making it possible to read the angle to minutes.

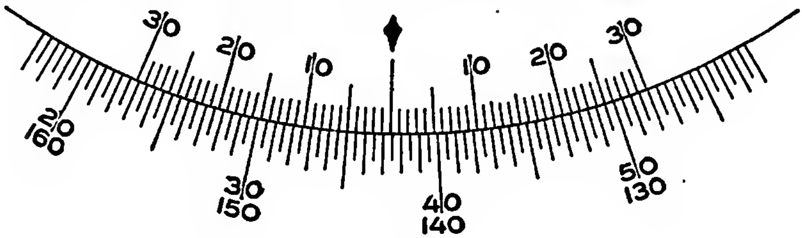


FIG. 5

This double vernier (really two verniers, the zero points of which coincide) is very common on transits. The object of this double vernier is to avoid the inconvenience of reading backward when the motion of the limb is reversed.

50. The principle of the vernier seems to be sufficiently explained in Art. 48. The student is advised to draw carefully on a sheet of paper a graduated scale, and to draw his vernier on the edge of a piece of cardboard. Then, by sliding this movable vernier along the main scale, he can practise reading any angle he pleases. On taking any instrument into his hands, he should first examine the vernier to ascertain its least count; that is, to learn what is the smallest reading that it will give. Should he be called upon to use a vernier with a peculiarity that he cannot master, let him write to the maker of the instrument for the desired information.

ADJUSTMENTS OF THE COMPASS

51. It is necessary for the surveyor to consider the adjustments of:

(1) The bubbles. (2) The standards. (3) The needle.

52. First, the Bubbles. — In attempting to "level" the compass, if it is found that the bubbles do not stay in the centre of the tube as the compass-plate is turned around, the compass is said to be out of adjustment, — the real difficulty being that the plane of the bubbles is not parallel to the plate.*

* This assumes that the plate has been made truly perpendicular to the spindle by the manufacturer.

To adjust the Bubbles. — Set up the instrument and bring the bubbles to the middle of the bubble-tube by pressure of the hands on the plate. Turn the compass half-way around, and if the bubbles remain at the middle, no adjustment is needed. If they do not, bring each half-way back to the middle by means of the screws at the ends. Level the plate again, and repeat the first operation until the bubbles will remain in the middle during an entire revolution of the plate.

53. Second, the Standards. — Observe through the slits a fine plumb-line, and if either sight fails to range with it, that sight must be adjusted by filing its under surface on the side that seems the highest.

54. Third, the Needle. — This adjustment is needed if the needle will not in any position cut opposite degrees. Having the eye nearly in the same plane with the graduated circle, with a small splinter of wood bring one end of the needle in line with any prominent graduation of the circle, as the zero, and notice whether the other end corresponds with the degree on the opposite side. If it does "cut" opposite degrees in this and any other position, the needle is in adjustment. If not, bend the centre pin (pivot) by applying a small wrench about one-eighth of an inch below the point of the pin until the ends of the needle are brought into line with the opposite degrees. Then, holding the needle in the same position, turn the plate half-way around, and note whether it now cuts opposite degrees; if not, correct half the error by bending the needle, and the remainder by bending the pivot. This operation should be repeated until perfect reversion is obtained. Then try again on another part of the circle, and, if any error appears, correct by bending the pivot only, the needle being already made straight by the previous operation.

55. Only the beginner in the study or practice of surveying could ask the question, Why cannot instruments be made so that no adjustment would be necessary? A partial answer to such a question, however, may not be out of place. One example will suffice: suppose the bubbles were rigidly secured to the plate and made exactly parallel to the plate (perpendicular to the vertical axis of the instrument) by the manufacturer. This essential relation may be disturbed in many ways. Even if the plate, or the level tube case, has not been bent by a fall or sudden jar, as may readily happen, changes of temperature, causing uneven expansion and contraction, or the ordinary

wearing of the axis, would soon throw the plane of the bubbles out of its proper position, and then in order to adjust the parts the instrument would have to be sent to a repair shop, involving expense and delay. Thus we see the wisdom of making those parts of all instruments liable to such derangement movable (or adjustable).

This all-important matter is always troublesome to the beginner; but he should be diligent in acquainting himself with the reason for every step, so that he can make each adjustment intelligently, and not in a purely mechanical way. The surveyor should test his instrument frequently. If it needs adjusting, there will usually be no practical difficulty in correcting the error, *provided* that the instrument has been firmly set and the operator handles the parts carefully. Every movement of the hand should be deliberate (not slow), and a jerky motion is always to be avoided.

THE USE OF THE COMPASS

56. True Meridian. — A meridian plane is any plane passing through the axis of the earth, and its intersection with the surface is a *meridian* (compare Art. 8).

57. Magnetic Meridian. — If a magnetic needle is suspended freely (as should be the case in the needle-compass) and allowed to come to rest, it will point toward the north magnetic pole,* and the intersection of the vertical plane containing the needle with the surface of the earth is called the *magnetic meridian.* Meridian lines converge toward the poles, but in limited surveys (such as ordinary farms) they may be considered parallel without appreciable error.

58. A *course* is a line measured on the ground. The *bearing of a course* is the angle which the course makes with the meridian.

59. The needle-compass is used to get the magnetic bearing of a line, or course. For example, to get the bearing of a course AB, set up the compass over the point A, level the plate, and sight a pole held at B; that is, put the *north* and *south* (N. and S.) line of the compass-box in line with AB, the south end being toward

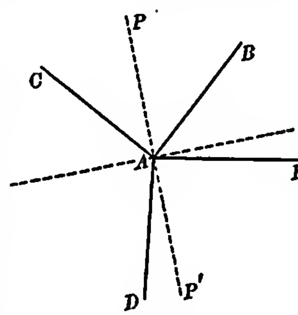


Fig. 6

* See Chapter III (ii).

the observer.* After the needle has come to rest, we read the angle (less than 90°) which it makes with the N. and S. line of the compass-box (in this case, 48°); the bearing is then N. 48° E. In our diagram PP' represents the position of the needle; that is, the magnetic meridian. We can now understand why the E. and W. points on the compass-circle are reversed. While the zero (N. and S.) line of the compass-circle points toward B, the needle points toward P, and the course being east of the needle, the needle is west of the course (or the zero line of the compass-circle). Were the circle lettered like the points of the compass on maps N. E. S. W. (clockwise), the surveyor would first read this bearing N. 48° W., and would then have to change it mentally to N. 48° E. It is to avoid the necessity of this mental change that the circle is lettered N. W. S. E. (clockwise).

If the bearing of AC was sought, the angle PAC being 40°, the reading would be N. 40° W. If $P'AD = 15°$, the bearing of AD is S. 15° W., and if $P'AE = 80°$, the bearing of AE is S. 80° E. Special field operations with the compass will be described in Chapter III.

THE SOLAR COMPASS

60. We give below a cut of Burt's solar compass, an instrument by means of which the bearing of a course with the true meridian is obtained by observations on the sun. The theory and use of this instrument will be discussed under the head of the Solar Attachment to the Transit (see Art. 76).

THE TRANSIT †

61. The transit was invented by Messrs. J. W. Young & Sons,‡ instrument-makers, of Philadelphia, in 1831. It differs from the theodolite, an instrument much used by English engineers, in that the telescope is constructed so that it can make a complete revolution on its horizontal axis. It is the most important of all the engineering instruments. Its immense value is due to the *telescope*, which gives precision in sighting, and the *graduated circle*, by which angles can be read with ease and accuracy. All the other parts

* The man with the instrument is often spoken of as the observer or operator.

† Often spoken of as the Surveyor's or Engineer's Transit, to distinguish it from an astronomical transit.

‡ Really by William J. Young, of whom J. W. Young & Sons are the successors.

facilitate the use of these. The essential parts, as shown in our cut, are the telescope with its axis and two standards, the circular plates with their attachments, the sockets upon which the plates revolve, the leveling-head, and the tripod upon which the whole instrument stands.

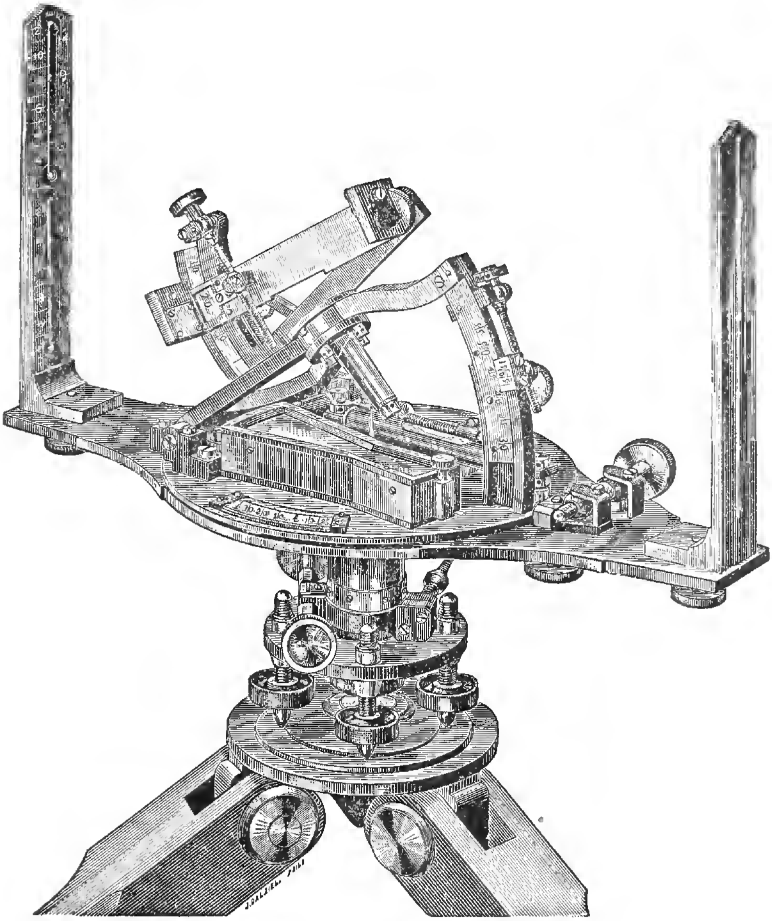


FIG. 7.—Solar Compass

62. The *telescope*,* which is usually from 10 to 11 in. long, is firmly secured to an axis, having its bearings fitted in the standards, which are high enough to allow the telescope to be turned completely over on its axis. A skeleton view of the telescope is given in

* For a more detailed description of a telescope, the student is advised to consult "Engineers' Surveying Instruments," by Ira O. Baker, or any good work on Physics.

Fig. 8. The object-glass is a compound, achromatic lens, and is placed at the end of a slide having two bearings, one at the end of the outer tube, the other in the ring *CC* suspended within the tube by four screws, only two of which are shown in the cut. Both the object-glass and eye-piece are moved in and out by pinions, and are thus adjusted to the proper focus. The eye-piece is made up of four lenses, which form a compound microscope having its focus in the plane of the cross-wire ring, *BB*. Sometimes an eye-piece with two lenses is employed; this arrangement gives an inverted image of the object seen, which is considered a disadvantage, and is seldom used by American engineers. It has, however, the decided advantage of giving more light, and should be employed in all high-grade instruments. The object-glass collects the rays of light which come from an object, converges them to a focus at the cross-wires, and there forms a minute, bright image, which the eye-piece, acting as a microscope, magnifies and conveys to the eye.

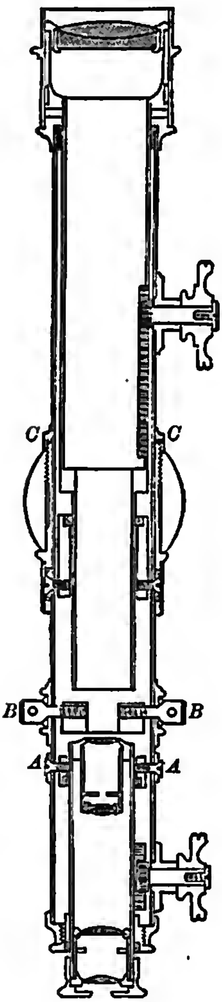


FIG. 8

The *cross-wires* are two wires of very fine platinum cemented into cuts on the surface of a metal ring called the reticule. Spider webs have been the favorite material for these wires, but platinum wires are rapidly replacing them. These wires are placed at right angles to each other, so as to divide the open space in the centre into quadrants. The reticule is held in place by four screws, two of which are shown in the cut at *BB*.

The *line of collimation*, or line of sight when the instrument is in adjustment, is the imaginary line passing through the intersection of the cross-wires and the optical centre of the object-glass. It is important that one of the wires should be exactly vertical, the other horizontal, when the instrument is set up and leveled; the vertical wire being used in measuring horizontal angles, and the horizontal in measuring vertical angles

or in using the instrument as a level. Many transits have two additional horizontal wires for stadia work, the use of which will be explained later.

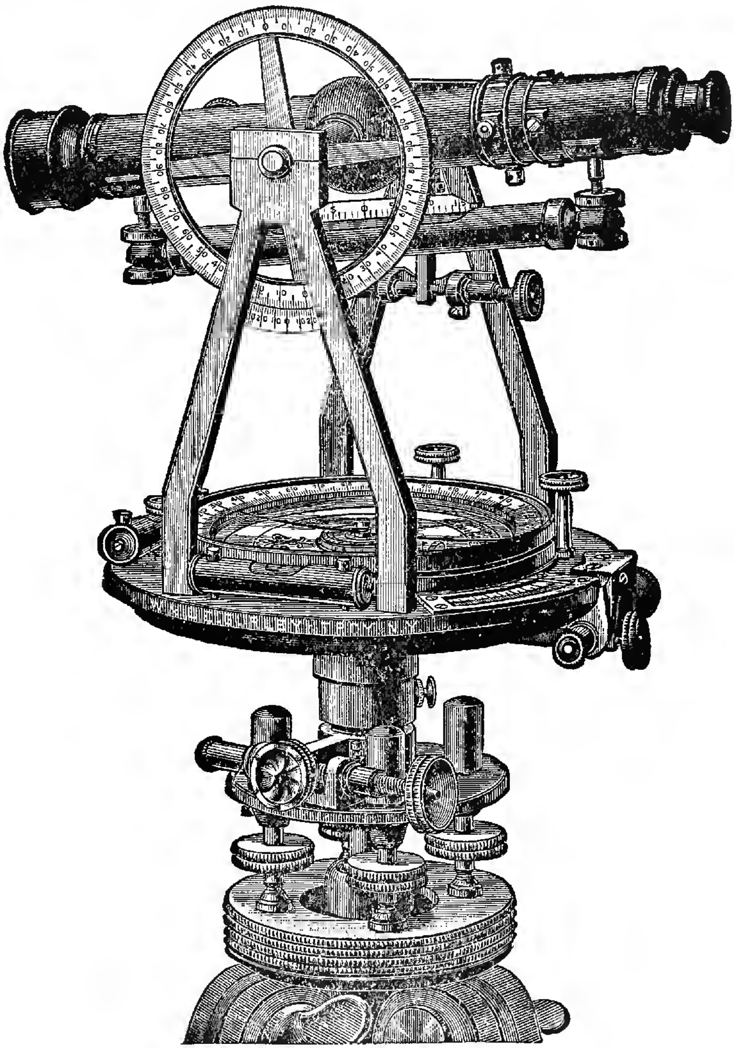


FIG. 9.—Surveyor's Transit

63. In the centre of the upper plate, between the standards, there is a compass-circle, with magnetic needle, which does not materially differ from that on the ordinary needle-compass. It may or may not have a vernier for setting off the variation of the needle. The

cut on page 21 represents the surveyor's transit as made by W. & L. E. Gurley, and below is given a sectional view of this instrument, showing the interior construction of the limbs, spindles, sockets, etc.

The transit proper, which rests upon the leveling-head rigidly attached to a tripod, consists of two plates, called the upper and lower plates, the former carrying the compass-circle, standards, etc., and the latter the graduated circle, which is read to minutes by means of a vernier on the upper plate. In this book we shall adopt the usage of calling the upper plate the *alidade*, the lower plate, the *limb*.* These plates have two concentric vertical axes. The alidade

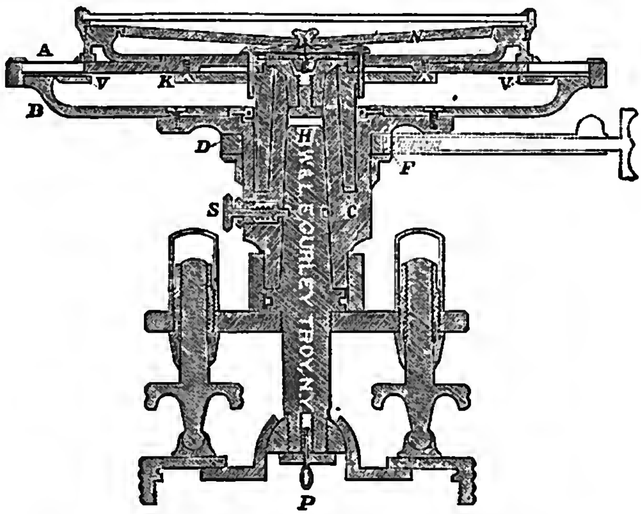


Fig. 10.—Sectional View of Transit

and limb may be firmly fastened together by a *clamp*, *DF* in the sectional view, to which is attached a *tangent screw* for giving them a slow motion around each other. The limb has another clamp and tangent screw to fix it to its spindle and to give it a slow motion around the spindle. When the plates are clamped together, the instrument turns as a whole about the spindle of the limb. The verniers *VV* are attached to the alidade diametrically opposite to each other. One vernier acts as a check upon the other. The alidade also carries the two bubbles, placed at right angles to each other, so that the instrument may be leveled in all directions. The limb (at *B* in sec-

* Sometimes called the *horizontal limb*, to distinguish it from the *vertical limb* (or circle) attached to the axis of the telescope.

tional view) is usually divided on its upper surface into degrees and half-degrees and figured in two rows from 0° to 360°, or from 0° to 90° each way.

The *leveling-head* consists of two plates connected in such a way that they are inclined to each other or made parallel at will by the four leveling-screws. The lower of these plates usually has a "shifting centre," which facilitates setting the plummet precisely over a point. The leveling-head is firmly screwed to the bronze head of the tripod.

In addition to the parts mentioned above, it is convenient, and often indispensable, to have a graduated vertical circle (as shown in our cut), or arc, attached to the axis of the telescope, and a bubble parallel to the telescope to which it is fastened. The telescope-bubble enables the surveyor to do leveling work with the transit, and both it and the vertical circle (or arc) are necessary for stadia work and for obtaining angles of elevation. When the bubble is in the centre, the vernier of the vertical arc should read zero.

ADJUSTMENTS OF THE TRANSIT

64. The four principal adjustments of the transit have to do with:

(1) The plate-bubbles.
(2) The line of collimation.
(3) The standards.
(4) The telescope-bubble.

65. First. — *To make the Plane of the Plate-bubbles Perpendicular to the Vertical Axis.* This adjustment is the same as for the needle-compass (see Art. 52).

66. Second. — *To make the Line of Sight* Perpendicular to the Horizontal Axis of the Telescope.*

When this is done, the line of sight will generate *a plane* when the telescope is revolved about its horizontal axis.

On tolerably level ground, having set up the transit and leveled it, sight a point (marked by a tack in a stake) 200 to 300 ft. distant, and clamp both the alidade and the limb; revolve the telescope about its horizontal axis, and mark a point at the same distance from the instrument in the opposite direction. Then loosen the upper clamp, and turn the instrument about its vertical axis until the first point is in line again, clamping the plates firmly together

* After adjustment the line of sight is the line of collimation (see Art. 62).

when this is done. Revolve the telescope about its horizontal axis, and sight toward the second point. If this is found to be in line, the transit is in adjustment, and is exactly on the straight line between the two points. If not, the intersection of the cross-wires should be brought back *one-fourth* of the distance to this second point by means of the pair of reticule screws on the sides of the telescope which move the vertical wire. This is done by loosening one screw and tightening the other.

Test by repetition, and, if need be, repeat the process till the adjustment appears perfect. The following explanation taken from Professor Lane's little book on adjustments * will make this process clear.

67. It is convenient here to use the following abbreviations:

A, horizontal axis of telescope.
C, line of collimation.
I, intersection of A and C.
S, axis of spindle.

Subscripts to A and C indicate their positions during different stages of the work.

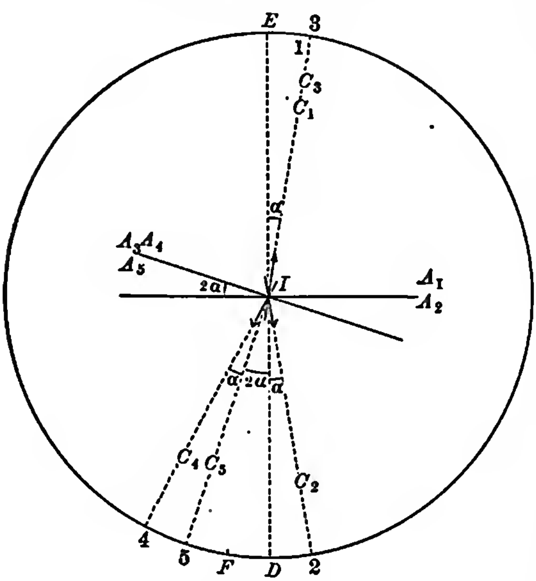


Fig. 11

"Assume a horizontal circle (Fig. 11) with centre I, and let C_1 differ α from IE, a perpendicular to A. Revolving C_1 about A_1 till it again cuts the circle, it takes the position C_2, differing α from ID, and therefore $180° - 2\alpha$ from C_1. Turning the instrument about S $180° - 2\alpha$, C_2 becomes C_3 in coincidence with C_1, while A_2 takes the position A_3. Revolving C_3 about A_3 until it again cuts the circle, it takes the position C_4, differing α from C_5 perpendicular to

* "Adjustments of the Compass, Transit, and Level," by A. V. Lane (Ginn & Co.).

A_5. C_5 and ID, respectively perpendicular to A_5 and A_2, differ by the same angle as those positions of the axis; viz. $2\,\alpha$. Since the arc 45 subtends α, $5\,D$ subtends $2\,\alpha$, and $D\,2$ subtends α, the ratio of the arc 45 to the arc 42 is clearly that of α to $4\,\alpha$, or one-fourth. If then C_4 were at C_5, one-fourth of the way toward C_2, it would be perpendicular to the horizontal axis of the telescope, and hence in adjustment."

NOTE.—Here and elsewhere when the instrument is said to be *set up*, it is understood that it is properly set up; that is, the legs are firmly planted in the ground, the plate (before using the leveling-screws) is reasonably level, and the plummet, when a station is occupied, is exactly over the point. The surveyor should see that no bystander puts his foot near a leg of the tripod, for by so doing he may readily throw the instrument out of its true position, especially in soft ground. See Art. 55 for other suggestions. There is more than one method for nearly all of the adjustments; the author gives the one that he prefers.

68. THIRD. — *To make the Horizontal Axis of the Telescope Perpendicular to the Axis of the Instrument.*

When this is done, the line of sight will generate a *vertical* plane as the telescope is revolved. To secure this result, the standards must be exactly of the same height; hence we have called this the standard adjustment. On nearly level ground in front of a high building, set up the transit at a distance about equal to the height of the building. Sight * a point (it is usually easy to find a well-defined mark that will serve the purpose) near the top of the wall, and, having clamped both the alidade and limb, lower the telescope till it is about horizontal; then find or mark a point in the line of sight near the bottom of the wall. Unclamp the plates, revolve the telescope about 180° on both the vertical and horizontal axes, and again sight the upper point. Clamp the plates and lower the telescope to the lower point. If the line of sight cuts this point, the standards are in adjustment. If not, correct one-half the difference by raising or lowering the adjustable end of the axis. Test by repeating.

69. FOURTH. — *To make the Axis of the Telescope-bubble Parallel to the Line of Sight.*

This adjustment is necessary only if the instrument is to be used as a level. Here we use the so-called "peg-adjustment," as follows: On a tolerably level piece of ground drive two pegs firmly into the

* Here and in other places the verb "sight" will be used as an abbreviation for "get the line of sight upon."

earth, about 200 or 300 feet apart. Set the instrument near one of them, say peg No. 1, so that when the leveling-rod* is held vertically upon it, the eye end of the telescope will swing about half an inch from its face. Turn the eye end of the telescope toward the face of the rod, the bubble being in the middle of its tube; look through the object end and set a pencil point on the rod at the centre of the small field of view. This pencil point gives the elevation of the instrument, which we will call a. Now hold the same rod on peg No. 2. With the object end toward the rod, being careful that the bubble is still in the middle of the tube, set the target and call the reading b. Next move the instrument and set it up near peg No. 2; get the height of the instrument, a', as was done at peg No. 1, by sighting through the object end the rod held on peg No. 2. Then set the target, in usual way, on the same rod held on peg No. 1, and call this reading b'.

Now, if the line of sight is parallel to the axis of the bubble, the difference between a and b must be equal to the difference between b' and a', because each of these differences represents the same thing; viz., the difference of elevation of the two pegs. Hence, if

$$a - b = b' - a', \tag{1}$$

no adjustment is necessary. If the instrument is not in adjustment, we have

$$a - b - (b' - a') = d, \tag{2}$$

or,

$$a + a' - (b + b') = d, \tag{3}$$

where d is twice the deviation of the line of sight from the axis of the bubble for the given distance; (3) shows that the line of sight inclines down when d is positive, and up when d is negative.

Correct the error by moving the target a distance equal to $\frac{1}{2}d$, *up* if d is *plus*, *down* if d is *minus*, get the line of sight by elevating or depressing the telescope,† and bring the telescope-bubble to the middle by means of the screw at the end of the bubble-tube; or else leave the telescope undisturbed with the bubble in the middle, and adjust the line of sight to read upon the target by moving the reticule. Notice that when this is being done the instrument is at its second position, near peg No. 2, and the rod is being held on peg No. 1. Repeat the process till no error is apparent.

The following example is given by way of illustration.

* See Art. 96.

† The simplest way of doing this with the transit is to revolve the telescope a little on its horizontal axis. If we were adjusting a Y-level, we should use the leveling-screws.

70. Peg adjustment of level (or transit with telescope-bubble).

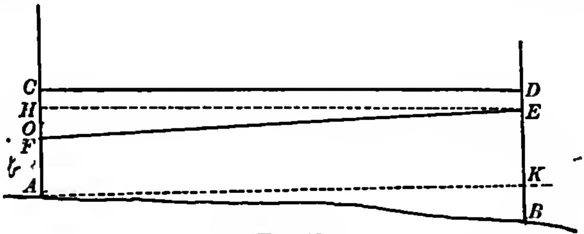


FIG. 12

$AC = a = 4.5,$ $\qquad (a + a') - (b + b') = d,$

$BD = b = 5.5,$

$BE = a' = 4.7,$ $\qquad (4.5 + 4.7) - (5.5 + 2.6) = d.$

$AF = b' = 2.6.$ $\qquad \therefore d = +1.1.$

AB is the natural slope of the ground where adjustment is made, peg No. 1 being at *A*, peg No. 2 at *B*.

AK is true horizontal or level line.* *CD* is line of sight in first position of the instrument, near *A*.

EF is line of sight in second position of the instrument, near *B*.

EH being drawn parallel to *DC*, $HF = d$; and if the target is moved to *O*, distant $\frac{1}{2}d$ above *F*, *OE* will be parallel to *AK*.

Hence, in this case, move the target *up* (because d is +) 0.55, and after getting the intersection of the cross-wires upon it, bring the bubble to the centre of its tube.

71. Other adjustments of the transit are occasionally required, but as the construction of instruments has reached such perfection as to render these unnecessary in most cases, they will not be given here.

THE USE OF THE TRANSIT

72. To measure a Horizontal Angle.—Set up the transit with the plummet exactly over the vertex of the angle. With the alidade clamped at zero for convenience (any other graduation point would answer) direct the telescope to some point on one side of the angle, as at *C*. A small tack driven into the top of a wooden peg is a convenient mark for a point. Then clamp the limb to the spindle and with the tangent screw get the line of sight exactly on the point. Then loosen the alidade and sight a point

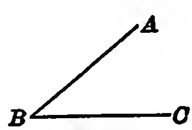


FIG. 13

* Neglecting the curvature of the earth.

on the other side of the angle, such as A; with the upper tangent screw bisect this point exactly and read the angle passed over from zero. This reading will be the value of the angle. As a check, and to counteract possible errors in graduation, both verniers should be read and the mean of the two readings taken if there is a slight difference.

73. To measure a Vertical Angle. — As one of its sides is usually horizontal, a vertical angle is generally an angle of elevation or depression (see Art. 12). If the vernier of the vertical arc reads zero when the telescope-bubble is in the centre of its tube, simply sight the point; the reading of the vertical arc gives at once its elevation or depression. If neither side of the angle is horizontal, the algebraic difference of the elevation (or depression) of the two sides gives the value of the vertical angle.

74. To produce a Straight Line with a Transit. — Knowing the direction that the line is to take from its initial point, A, set up the instrument over this point, and set another point, B, at a convenient distance along the line. Then move the transit and set it up over B.

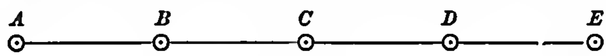


FIG. 14

Sight the first point, A, then, having both plates clamped, revolve the transit on its horizontal axis and fix another point, C, which (if the instrument is in adjustment) will be on the prolongation of the line AB. Then move the instrument to C, sight back to B, and, having the plates clamped, revolve the telescope as before and fix another point, D, at some convenient distance ahead. By continuing the process, a line may be prolonged indefinitely.

Further use of the transit will be explained when we take up the subject of Transit Surveying.

THE SOLAR ATTACHMENT

75. The solar compass, an instrument contrived for determining a true meridian, was invented by William A. Burt, of Michigan, and patented by him in 1836. It came into general use in the surveys of the United States public lands. Its great superiority over the needle-compass lies in the fact that the bearings of lines are determined with reference to the true meridian and not to the varying magnetic meridian. It will be seen from Fig. 7, page 19, that

the solar apparatus takes the place of the needle. The work, however, can be done with more ease and accuracy by the use of the transit with a solar attachment, and as the principle is the same, we shall not enter into any description of the solar compass.

76. The solar attachment as made by Messrs. W. & L. E. Gurley (Fig. 15, page 30) is essentially the solar apparatus of Burt, placed upon the cross-bar of the ordinary transit, the polar axis being directed above instead of below as in the solar compass. This cut also serves to give a graphic illustration of the theory of the solar apparatus. It will be understood by reference to definitions, Arts. 13 to 29.

The polar axis of the attachment is connected by means of four screws with a disk, which is securely screwed to the telescope axis.

The *hour-circle* surrounding the base of the polar axis is easily movable about it, and can be fastened at any point desired by two flat-head screws above. It is divided to 5′ of time, is figured from I to XII, and is read by a small index fixed to the declination arc and moving with it.

The *declination arc* has a radius of about five inches and is divided to quarter degrees. Its vernier, reading to half minutes, is fixed to a movable arm, at each end of which is a rectangular block of brass in which is set a small convex lens, having its focus on the silver plate *A* (see page 31) on the opposite block. The arc of the declination limb is turned on its axis and one or the other solar lens used, as the sun is north or south of the equator; the cut shows its position when the sun is north.

Latitude Arc.—The latitude is set off by means of the large vertical limb of the transit, graduated from the centre each way. The usual tangent movement to the telescope axis serves to bring the vertical limb to the proper elevation. A telescope-bubble (on under side of the telescope) is indispensable in the use of the solar attachment.

THEORY OF THE SOLAR ATTACHMENT

77. In our diagram the circles shown are intended to represent those supposed to be drawn upon the concave surface of the heavens. Compare Fig. 1, page 5. When the telescope is set horizontal by its bubble, the hour-circle will be in the plane of the horizon, the polar axis will point to the zenith, and the zeros of the vertical arc and its vernier will coincide. Now, if we incline the telescope, directed north, as shown in the cut, the polar axis will descend,

from the direction of the zenith, through an angle, laid off on the vertical arc, equal to the co-latitude * of the place where the instrument is supposed to be used. Then, when the sun is on the equator (at the vernal and autumnal equinox), the telescope and the

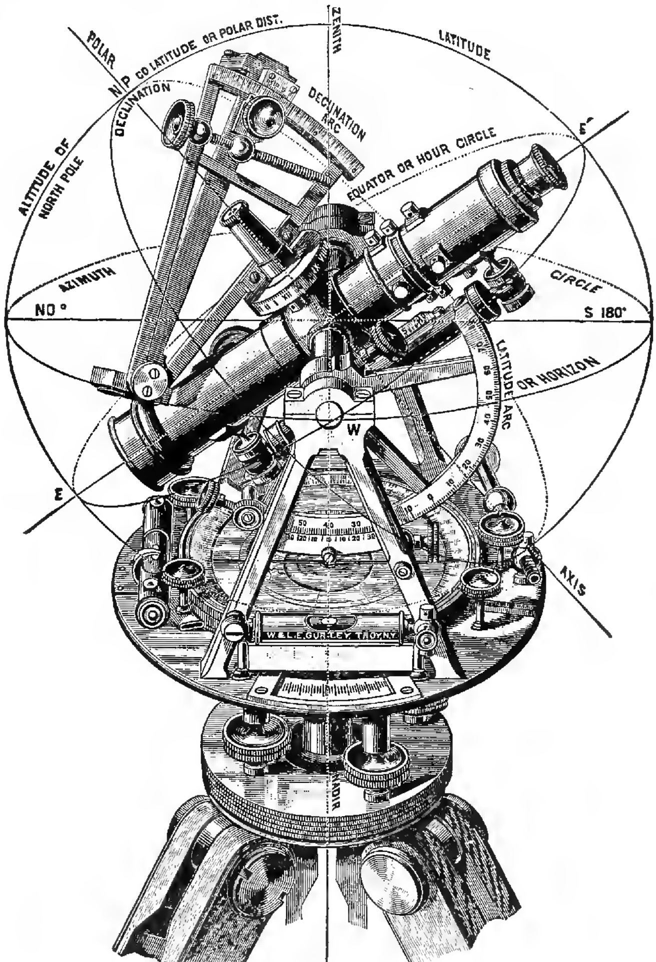


FIG. 15.—Solar Attachment

arm of the declination arc, if fixed at zero, will "follow" the path of the sun when the transit is revolved about its vertical axis. When, however, the sun passes above or below the equator, his declination † can be set off upon the arc, the arm carrying the lenses

* That is 90° – the latitude. † Art. 27.

can be made to follow his path as before, and his image brought into proper position.

In order to do this, it is necessary not only that the latitude and declination be correctly set off upon their respective arcs, but also that the instrument be moved in azimuth * until the polar axis points to the pole of the heavens, or in other words, is placed in the plane of the meridian; and thus the position of the sun's image will indicate not only the latitude of the place, the declination of the sun for the given hour and the apparent time, but it will also determine the meridian or true north and south line passing through the place where the observation is made.

The interval between the two equatorial lines, *cc*, as well as between the hour lines *bb*, is just sufficient to include the circular image of the sun, as formed by the solar lens on the opposite end of the revolving arm. When the solar attachment is accurately adjusted and the plates of the transit made perfectly horizontal, the latitude of the place and the declination of the sun for the given day and hour being also set off on their respective arcs, and the instrument set approximately north by the magnetic needle, *the image of the sun cannot be brought between the equatorial lines until the polar axis is placed in the plane of the meridian of the place, or in a position parallel with the axis of the earth.*

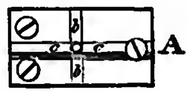


FIG. 16

Thus we obtain for our reference line a true *north* and *south line*, for the slightest deviation from this position will cause the image to pass to one side or the other of the lines.

The weak point of this form of attachment is that the naked eye must determine when the sun's image is exactly in position. The method of running lines with this attachment will be understood from the explanation of the mode of using the improved form of solar attachment described below.

78. To Adjust the Solar Attachment.—The surveyor should first see that the transit itself is in perfect adjustment. There are then three principal adjustments of the attachment.

FIRST.—*To adjust the Solar Lenses and Lines.* Remove the declination arm and replace it by the adjuster, a short bar furnished with the instrument. Now place the declination arm upon the adjuster, turn one end to the sun, and bring it into such a position that the image of the sun is precisely between the equatorial lines on the opposite plate. Turn the arm over (not end for end), and again observe the sun's image. If it remains between the lines as before, the arm is in adjust-

* Revolved about its vertical axis.

ment. If not, loosen the three small screws which hold it to the arm and move the silver plate under their heads until one-half the error is removed. Bring the image again between the lines, and repeat the operation as above on both ends of the arm, until the image will remain between the lines of the plate in both positions of the arm, when it will be in adjustment, and the arm may be replaced in its former position on the attachment.

SECOND. — *To adjust the Vernier of the Declination Arc.* Set the vernier at zero, and with one lens toward the sun bring his image exactly between the equatorial lines on opposite plate. Clamp the telescope axis and revolve the arm until the image appears on the other plate. If precisely between the lines, the adjustment is complete; if not, move the declination arm till the image is centred, clamp the arm, and correct one-half the apparent index error by loosening the two screws that hold the vernier and moving the vernier. Test again.

THIRD.—*To adjust the Polar Axis.* This consists in making the polar axis perpendicular to the axis of the telescope. Level the instrument with the plate-bubbles in connection with the long telescope-bubble, until the latter will appear in the middle of its tube during a complete revolution of the transit upon its spindle.

Bring the declination arm of the solar apparatus in the same vertical plane with the telescope, place the *adjusting level* (which comes with the solar attachment) upon the top of the rectangular blocks, and bring the bubble of this level into the middle by the tangent screw of the declination arc. Then turn the arc half-way around, making it parallel to the telescope, and note the position of the bubble. If in the middle, the polar axis is vertical in that direction; if not, correct one-half of the error by the adjusting screws under the base of the polar axis. Test by repeating the operation. Pursue the same course in adjusting the arc in the second position, over the telescope axis. When this is done, the bubble will remain in the middle during an entire revolution of the arc, and the adjustment is completed. This is the most delicate and important adjustment of the solar attachment.

It is sometimes necessary to adjust the *hour-arc.* As the index of the hour-arc should read apparent time, the method of making this adjustment will readily suggest itself.

THE SAEGMULLER SOLAR ATTACHMENT

79. The Saegmuller solar attachment * seems to be superior to any form † yet devised. Fig. 17, page 33, shows a transit with the Saegmuller attachment, which can be put on any transit that possesses a telescope-bubble and vertical circle. The improved attachment, as now made, is shown in Fig. 18.

It consists essentially of a small telescope and level, the telescope being mounted in standards, in which it can be elevated or depressed. The standard revolves around an axis, called the polar axis, which is fastened to the telescope axis of the transit instrument.

* Invented by G. N. Saegmuller, of Washington, D.C., in 1881, and manufactured by him and other instrument-makers.

† A similar form is made by C. L. Berger & Sons, Boston, Mass.

The telescope, called the "solar telescope," can thus be moved in altitude and azimuth. Two pointers attached to the telescope tc

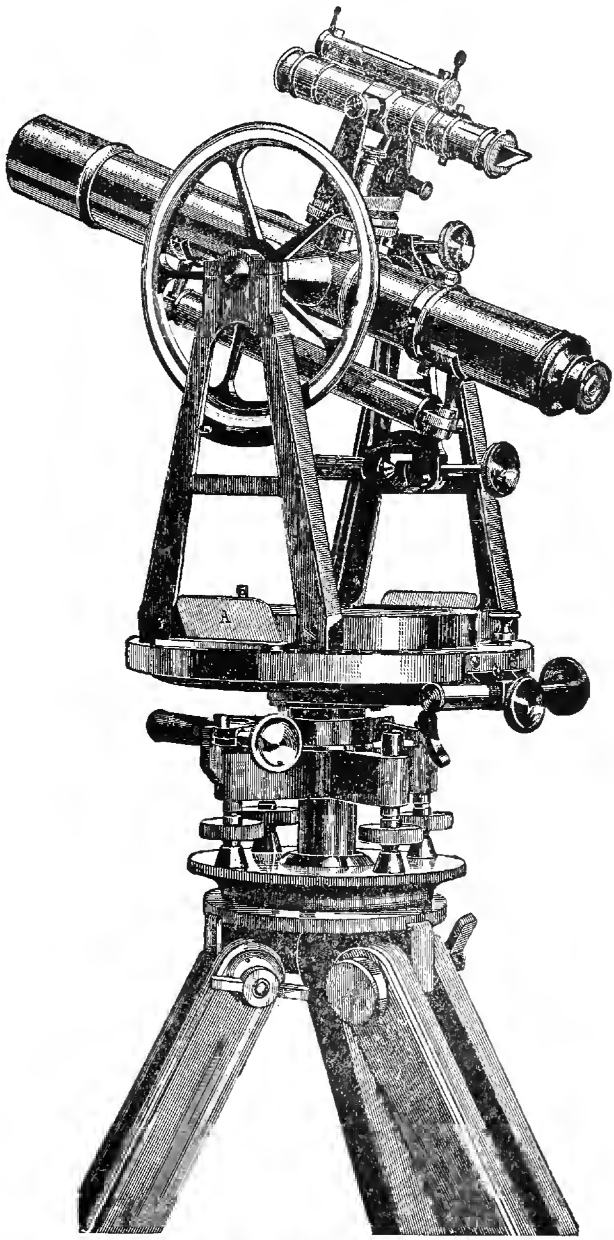


FIG. 17.—Transit with Saegmuller Solar Attachment

approximately set the instrument are so adjusted that when the shadow of the one is thrown on the other the sun will appear in the field of view.

ADJUSTMENT OF THE APPARATUS

80. FIRST. — The transit must be in perfect adjustment, especially the levels on the teleseope and the plates; the cross-axis of the telescope should be exactly horizontal, and the index error of the vertical circle carefully determined.

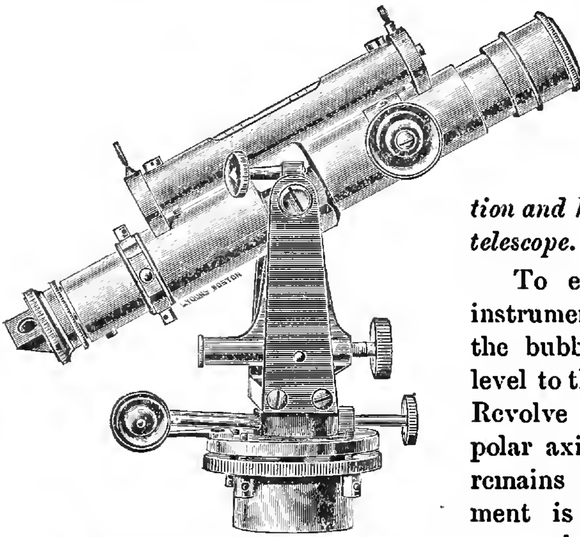


FIG. 18. — Saegmuller Solar Attachment

SECOND. — *The polar axis must be at right angles to the line of collimation and horizontal axis of main telescope.*

To effect this, level the instrument carefully and bring the bubble of each telescope level to the middle of its scale. Revolve the solar around its polar axis, and if the bubble remains central, the adjustment is complete. If not, correct half the movement by the adjusting screws at the base of the polar axis, and the other half by moving the solar telescope on its horizontal axis.

THIRD. — *The line of collimation of the solar telescope and the axis of its level must be parallel.*

To effect this, bring both telescopes into the same vertical plane and both bubbles to the middle of their scales. Observe a mark through the transit telescope, and note whether the solar teleseope points to a mark above this, equal to the distance between the horizontal axes of the two telescopes. If it does not bisect this mark, move the cross-wires by means of the screws until it does. Generally the small level has no adjustments, and the parallelism is effected only by moving the cross-hairs.

The adjustments of the transit and the solar should be *frequently* examined, and kept as nearly perfect as possible.

DIRECTIONS FOR USING THE ATTACHMENT.

81. FIRST. — Take the declination of the sun as given in the "Nautical Almanac" * for the given day, and correct it for refraction and hourly change. Incline the *transit telescope* until this amount is indicated by its vertical arc. If the declination of the sun is north, depress it; if south, elevate it. Without disturbing the position of the transit telescope, bring the solar telescope into the vertical plane of the large telescope and to a horizontal position by means of its level. The two telescopes will then form an angle which equals the amount of the declination, and the inclination of the solar telescope to its polar axis will be equal to the polar distance of the sun.

SECOND. — Without disturbing the *relative* positions of the two telescopes, incline them and set the vernier to the co-latitude of the place.

By moving the transit and the solar attachment around their respective *vertical* axes, the image of the sun will be brought into the field of the solar telescope; after accurately bisecting this image the *transit telescope must be in the meridian, and the compass-needle indicates its deviation at that place.*

The vertical axis of the solar attachment will then point to the pole, the apparatus being in fact a small equatorial.

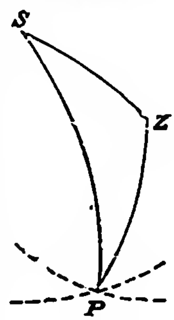


FIG. 18 *a*

Time and azimuth are calculated from an observed altitude of the sun by solving the spherical triangle formed by the sun, the pole, and the zenith of the place. The three sides, *SP*, *PZ*, *ZS*, complements respectively of the declination, latitude, and altitude, are given; hence we deduce *SPZ*, the hour-angle, from apparent noon, and *PZS* the azimuth of the sun.

The solar attachment solves the same spherical triangle by construction, for the second process brings the vertical axis of the solar telescope to the required distance, *ZP*, from the zenith, while the first brings it to the required distance, *SP*, from the sun.

OBSERVATION FOR TIME

82. If the two telescopes, both being in position — one in the meridian, and the other pointing to the sun — are now turned on their *horizontal* axes, the vertical remaining undisturbed until each

* "American Ephemeris and Nautical Almanac" for each year is published several years in advance by the United States government.

is level, the angle between their directions (found by sighting on a distant object) is *SPZ*, the time from apparent noon.

This gives an easy observation for correction of timepiece, reliable within a few seconds.

TO OBTAIN THE LATITUDE WITH THE SAEGMULLER SOLAR ATTACHMENT

83. Level the transit carefully, point the telescope toward the south and elevate or depress the object end, according as the declination of the sun is south or north, an amount equal to the declination.

Bring the solar telescope into the vertical plane of the main telescope, level it carefully and clamp it. With the solar telescope observe the sun a few minutes before its culmination; bring its image between the two horizontal wires by moving the *transit telescope* in *altitude* and *azimuth*, and keep it so by the slow-motion screws until the sun ceases to rise. Then take the reading of the vertical arc, and correct for refraction due to altitude by the table below. Subtract the result from 90°, and the remainder is the latitude sought.

TABLE I

MEAN REFRACTION

Barometer 30 inches, Fahrenheit thermometer 50°

Altitude	Refraction	Altitude	Refraction
10°	5′ 19″	20°	2′ 39″
11	4 51	25	2 04
12	4 27	30	1 41
13	4 07	35	1 23
14	3 49	40	1 09
15	3 31	45	58
16	3 20	50	49
17	3 08	60	34
18	2 57	70	21
19	2 48	80	10

The following table, computed by Professor Johnson, C. E., Washington University, St. Louis, will be found of considerable value in solar compass work.

"This table is valuable in indicating the errors to which the work is liable at different hours of the day and for different latitudes, as well as in serving to correct the observed bearings of lines when it afterwards appears that a wrong latitude or declination has been

used. Thus, on the first day's observations I used a latitude in the forenoon of 38° 37′, but when I came to make the meridian observation for latitude I found the instrument gave 38° 39′. This was the latitude that should have been used, so I corrected the morning's observations for two minutes error in latitude by this table.

"It is evident that if the instrument is out of adjustment, the latitude found by a meridian observation will be in error; but *if this observed latitude be used* in setting off the co-latitude, the instrumental error is eliminated. Therefore always use for the co-latitude that given by the instrument itself in a meridian observation."

TABLE II

ERRORS IN AZIMUTH (BY SOLAR COMPASS) FOR ONE MINUTE ERROR IN DECLINATION OR LATITUDE

Hour	For 1 Min. Error in Declination			For 1 Min. Error in Latitude		
	Lat. 30°	Lat. 40°	Lat. 50°	Lat. 30°	Lat. 40°	Lat. 50°
	Min.	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*
11.30 A.M. . . . / 12.30 P.M. . . .	8.85	10.00	12.90	8.77	9.92	11.80
11 A.M. . . . . . / 1 P.M.	4.46	5.05	6.01	4.33	4.87	5.80
10 A.M. . . . . . / 2 P.M.	2.31	2.61	3.11	2.00	2.26	2.70
9 A.M. . . . . . / 3 P.M.	1.63	1.85	2.20	1.15	1.30	1.56
8 A.M. . . . . . / 4 P.M.	1.34	1.51	1.80	0.67	0.75	0.90
7 A.M. . . . . . / 5 P.M.	1.20	1.35	1.61	0.31	0.35	0.37
6 A.M. . . . . . / 6 P.M.	1.15	1.30	1.56	0.00	0.00	0.00

NOTE.—Azimuths observed with erroneous declination or co-latitude may be corrected by means of this table by observing that for the line of collimation set *too high* the azimuth of any line *from the south point* in the direction S. W. N. E. is found *too small* in the *forenoon* and *too large* in the *afternoon* by the tabular amounts for each minute of error in the altitude of the line of sight. The reverse is true for the line set too low.

84. From the last three articles we gather that an observation with the solar transit involves four quantities; viz. (1) the hour-angle of the sun, or time of day; (2) the declination of the sun:

(3) the latitude of the place of observation; and (4) the direction of the true meridian. The prime object of the solar instrument is to find the true meridian, the other three elements being known.

85. The time of day may be conveniently found by the method of Art. 82. The latitude of the place of observation may be determined by observations on a circumpolar star (see Art. 147); but for this particular work it had best be obtained by the method of Art. 83.

86. To find the Declination of the Sun. — The declination of the sun is his angular distance north or south of the equator measured on an hour-circle (Art. 27, and Fig. 1). About the 20th of March the sun crosses the equator, going north, and continues to move north till June 21, when he reaches his farthest point north and turns and comes south, recrossing the equator about Sept. 20, and continuing his southward motion till about Dec. 21, when he turns north again, reaching the equator once more on March 20. Thus his declination is *zero* at the time of the vernal and autumnal equinoxes, and it has its maximum north (or +) value on June 21 and its maximum south (or −) value on Dec. 20. In June and December the sun's declination is changing most slowly, while in March and September it is changing most rapidly. For solar work, therefore, we need a table giving the declination for each hour of the day; these values are spoken of as the declination "settings" for the day's work.

The "American Ephemeris and Nautical Almanac" gives the declination of the sun for noon of each day of the year for Greenwich and Washington, with the hourly correction for the declination. As our "standard" time is so many hours west of Greenwich, it is more convenient to use Greenwich declinations. Then the noon Greenwich declinations will correspond to declinations at 7, 6, 5, or 4 o'clock A.M., according as *Eastern*, *Central*, *Mountain*, or *Western* time is used, for these time-belts are respectively 5, 6, 7, and 8 hr. west of Greenwich. Now as the standard time seldom differs more than 30 min. at most from local time, and as a difference of 30 min. could never change the declination more than 30 sec. of arc, it is sufficiently accurate to use the standard time of the place of observation in applying the hourly change in the declination. Suppose, for example, a solar survey is to be made near Nashville, which is in the "Central" (90th meridian) time belt. The declination given in the "Almanac" is the declination at 6 o'clock A.M. at the place of observation. For any other hour, the hourly change in declination must be added (algebraically) to this.

87. To correct the Declination for Refraction. — Declination is affected by refraction, which causes rays of light to be bent downward on entering the earth's atmosphere, thus making the object appear higher in the heavens than it really is. The "Nautical Almanac"* gives the *apparent* declination for noon; for any other time of the day, a correction for refraction must be applied. In Table III are given the refraction corrections for latitude 40°, and in Table IV are given the so-called *latitude coefficients*, used for getting the corrections for any other latitude. To obtain the proper refraction correction for a place whose latitude is 36°, for example, we multiply the value taken from Table III by the latitude coefficient of Table IV corresponding to 36°.

TABLE III

REFRACTION CORRECTION, LAT. 40°

January	hr. ′ ″
1	1 1 58
2	2 2 16
	3 3 04
3	4 6 23
4	1 1 54
5	2 2 11
6	
7	3 2 59
8	4 6 01
9	1 1 51
10	2 2 07
11	
12	3 2 51
13	4 5 40
14	1 1 46
15	2 2 01
16	
17	3 2 40
18	4 5 00
19	1 1 42
20	2 1 56
21	
22	3 2 31
23	4 4 35
24	1 1 37
25	2 1 58
26	
27	3 2 22
28	4 4 07
29	1 1 32
30	2 1 44
	3 2 13
31	4 3 41

February	hr. ′ ″
1	
2	
3	1 1 26
4	2 1 37
5	
6	3 2 04
7	4 3 21
8	1 1 21
9	2 1 31
10	
11	3 1 56
12	4 3 01
13	1 1 16
14	2 1 25
15	3 1 48
16	4 2 47
17	5 8 39
18	1 1 12
19	2 1 20
20	3 1 40
21	4 2 31
22	5 6 49
23	1 1 07
24	2 1 15
25	3 1 33
26	4 2 18
27	5 5 28
28	

March	hr. ′ ″
1	1 1 03
2	2 1 10
	3 1 27
3	4 2 06
4	5 4 39
5	1 0 59
6	2 1 06
7	3 1 21
8	4 1 56
9	5 4 04
10	1 0 55
11	2 1 02
12	3 1 15
13	4 1 47
14	5 3 34
15	1 0 52
16	2 0 58
17	3 1 10
18	4 1 39
19	5 3 08
20	1 0 48
21	2 0 54
22	3 1 05
23	4 1 32
24	5 2 51
25	1 0 45
26	2 0 50
27	3 1 01
28	4 1 25
29	5 2 34
30	1 0 42
31	2 0 47

April	hr. ′ ″
1	3 0 57
2	4 1 19
3	5 2 18
4	1 0 39
5	2 0 44
6	3 0 54
7	4 1 14
8	5 2 08
9	1 0 36
10	2 0 41
11	3 0 51
12	4 1 10
13	5 1 58
14	1 0 34
15	2 0 38
16	3 0 48
17	4 1 06
18	5 1 49
19	1 0 32
20	2 0 36
21	3 0 45
22	4 1 02
23	5 1 42
24	1 0 30
25	2 0 34
26	3 0 42
27	4 0 58
28	5 1 36
29	1 0 28
30	2 0 32

May	hr. ′ ″
1	1 0 28
	2 0 32
2	3 0 39
	4 0 55
3	5 1 30
4	1 0 26
5	2 0 30
6	3 0 37
7	4 0 53
8	5 1 26
9	1 0 25
10	2 0 29
11	3 0 36
12	4 0 51
13	5 1 22
14	1 0 23
15	2 0 27
16	3 0 34
17	4 0 49
18	5 1 18
19	1 0 22
20	2 0 26
21	3 0 33
22	4 0 47
23	5 1 15
24	1 0 21
25	2 0 25
26	3 0 32
27	4 0 46
28	5 1 13
29	1 0 20
	2 0 24
30	3 0 31
	4 0 44
31	5 1 11

June	hr. ′ ″
1	5 1 11
2	
3	1 0 19
4	2 0 23
5	3 0 30
6	4 0 43
7	5 1 10
8	1 0 18
9	2 0 22
10	3 0 29
11	4 0 43
12	5 1 09
13	1 0 18
14	2 0 22
15	3 0 29
16	4 0 42
17	5 1 08
18	1 0 18
19	2 0 22
20	3 0 28
21	4 0 42
22	5 1 08
23	1 0 18
24	2 0 22
25	3 0 29
26	4 0 42
27	5 1 08
28	1 0 18
	2 0 22
29	3 0 29
30	4 0 43

* "The Solar Ephemeris and Refraction Tables," for the use of surveyors, are published yearly by George N. Saegmuller, Washington, D.C., W. & L. E. Gurley, Troy, N.Y., and other instrument-makers.

TABLE III — *Continued*

July		August		September		October		November		December	
	hr. ′ ″		hr. ′ ″		hr. ′ ″		hr. ′ ″		hr. ′ ″		hr. ′ ″
1	5 1 09	1		1	1 0 39	1	1 0 59	1	2 3 21	1	1 1 54
2				2	2 0 44	2	2 1 06	2	313 57	2	2 2 11
3	1 0 19	2	1 0 26	3	3 0 54	3	3 1 21	3	4		3 2 59
4	2 0 23	3	2 0 30	4	4 1 14	4	4 1 56	4	5	3	4 6 01
5	3 0 30	4	3 0 37	5	5 2 08	5	5 4 04	5	1 1 32	4	5
6	4 0 43	5	4 0 53	6	1 0 42	6	1 1 03	6	2 1 44	5	1 1 58
7	5 1 10	6	5 1 26	7	2 0 47	7	2 1 10	7	3 2 13	6	2 2 16
8	1 0 20	7	1 0 28	8	3 0 57	8	3 1 27	8	4 3 41	7	3 3 04
9	2 0 24	8	2 0 32	9	4 1 19	9	4 2 06	9	5	8	4 6 23
10	3 0 31	9	3 0 39	10	5 2 18	10	5 4 39	10	1 1 37	9	5
11	4 0 44	10	4 0 55	11	1 0 45	11	1 1 07	11	2 1 50	10	1 2 00
12	5 1 11	11	5 1 30	12	2 0 50	12	2 1 15	12	3 2 22	11	2 2 19
13	1 0 21	12	1 0 30	13	3 1 01	13	3 1 33	13	4 4 07	12	3 3 09
14	2 0 25	13	2 0 34	14	4 1 25	14	4 2 18	14	5	13	4 6 38
15	3 0 32	14	3 0 42	15	5 2 34	15	5 5 39	15	1 1 42	14	5
16	4 0 46	15	4 0 58	16	1 0 48	16	1 1 12	16	2 1 56	15	1 2 01
17	5 1 13	16	5 1 36	17	2 0 54	17	2 1 20	17	3 2 31	16	2 2 20
18	1 0 22	17	1 0 32	18	3 1 05	18	3 1 40	18	4 4 35	17	3 3 11
19	2 0 26	18	2 0 36	19	4 1 32	19	4 2 31	19	5	18	4 6 47
20	3 0 33	19	3 0 45	20	5 2 51	20	5 6 29	20	1 1 46	19	5
21	4 0 47	20	4 1 02	21	1 0 52	21	1 1 16	21	2 2 01	20	1 2 01
22	5 1 15	21	5 1 42	22	2 0 58	22	2 1 25	22	3 2 40	21	2 2 20
23	1 0 23	22	1 0 34	23	3 1 10	23	3 1 48	23	4 4 59	22	3 3 11
24	2 0 27	23	2 0 38	24	4 1 39	24	4 2 47	24	5	23	4 6 49
25	3 0 34	24	3 0 48	25	5 3 08	25	5 8 39	25	1 1 50	24	5
26	4 0 49	25	4 1 06	26	1 0 55	26	1 1 21	26	2 2 06	25	1 2 00
27	5 1 18	26	5 1 49	27	2 1 02	27	2 1 31	27	3 2 49	26	2 2 19
28	1 0 25	27	1 0 36	28	3 1 15	28	3 1 56	28	4 5 33	27	3 3 09
29	2 0 29	28	2 0 41	29	4 1 47	29	4 3 01	29	5	28	4 6 43
	3 0 36	29	3 0 51	30	5 3 34	30	5 11 01	30		29	5
30	4 0 51	30	4 1 10				1 1 26			30	
31	5 1 22	31	5 1 58			31	1 37			31	
							2 04				

88. To prepare the Declination Settings for a Day's Work. — From the preceding articles, we are now in a position to understand the method of preparing the declination settings, which we shall illustrate by two examples.

(1) *Let it be required to prepare a table of declination settings for a point whose latitude is* 35°, *and which lies in the "Central Time" belt, for April* 4, 1901.

Since the time is 6 hr. earlier than at Greenwich, the declination given in the ephemeris is the declination here at 6 A.M. of the same date. This is found to be $+5° 32' 6''$. Adding the hourly change, $+57''.32$, this becomes, for 7 A.M., $+5° 33' 3''$. The latitude coefficient is .82 and the refraction correction for 7 A.M. is, therefore,

$$.82 \times 2' 18'' = 1' 53''.$$

Therefore, for 7 A.M., the setting is $5° 34' 56''$. Notice that to get the refraction correction for 8 A.M., we have $.82 \times 1' 19'' = 1' 5''$.

Thus we make out the following table, which gives the declination settings for the hours during which the work is likely to be done:

DECLINATION SETTINGS FOR APR. 4, 1901, LAT. 35°, CENTRAL TIME

HOUR	DECLINATION	REFR. COR.	SETTINGS	HOUR	DECLINATION	REFR. COR.	SETTINGS
	° ′ ″	′ ″	° ′ ″		° ′ ″	′ ″	° ′ ″
7	+5 33 3	+1 53	5 34 56	1	+5 38 47	+0 32	5 39 19
8	+5 34 0	+1 5	5 35 5	2	+5 39 44	+0 36	5 40 20
9	+5 34 58	+0 47	5 35 45	3	+5 40 42	+0 47	5 41 29
10	+5 35 55	+0 36	5 36 31	4	+5 41 39	+1 5	5 42 44
11	+5 36 52	+0 32	5 37 24	5	+5 42 36	+1 53	5 44 29

(2) *Let it be required to prepare a declination table for a point in latitude* 45°, *in the "Eastern Time" belt, for Oct.* 10, 1890.

The time now is 5 hr. earlier than that of Greenwich, hence the declination given in the ephemeris for Greenwich mean noon is the declination at our point at 7 A.M. The declination found is $-6° 43' 56''$, and the hourly change is $-56'.87$. The latitude coefficient is 1.20.

The table then becomes:

DECLINATION SETTINGS FOR OCT. 10, 1890, LAT. 45°, EASTERN TIME

HOUR.	DECLINATION	REFR. COR.	SETTINGS.	HOUR.	DECLINATION	REFR. COR.	SETTINGS.
	° ′ ″	′ ″	° ′ ″		° ′ ″	′ ″	° ′ ″
7	−6 43 56	+5 35	−6 38 21	1	−6 49 37	+1 16	−6 48 21
8	−6 44 53	+2 31	−6 42 22	2	−6 50 34	+1 24	−6 49 10
9	−6 45 50	+1 44	−6 44 06	3	−6 51 31	+1 44	−6 49 47
10.	−6 46 47	+1 24.	−6 45 23	4	−6 52 28	+2 31	−6 49 57
11	−6 47 44	+1 16	−6 46 28	5	−6 53 25	+5 35	−6 47 50

If the date be between June 20 and Sept. 20, the declination is positive and the hourly change negative, while if it be between Dec. 20 and March 20, the declination is negative and the hourly change positive. The refraction correction is always positive; that is, it always increases numerically the north declinations and diminishes numerically the south declinations. The hourly refraction corrections given in the ephemeris are exact for the middle day of the five-day period corresponding to that set of hourly corrections. For the

extreme days of any such period an interpolation can be made between the adjacent hourly corrections, if desired.

TABLE IV

LATITUDE COEFFICIENTS

LAT.	COEFF.	LAT.	COEFF.	LAT.	COEFF.	LAT.	COEFF.
15°	.30	27°	.56	39°	.96	51°	1.47
16	.32	28	.59	40	1.00	52	1.53
17	.34	29	.62	41	1.04	53	1.58
18	.36	30	.65	42	1.08	54	1.64
19	.38	31	.68	43	1.12	55	1.70
20	.40	32	.71	44	1.16	56	1.76
21	.42	33	.75	45	1.20	57	1.82
22	.44	34	.78	46	1.24	58	1.88
23	.46	35	.82	47	1.29	59	1.94
24	.48	36	.85	48	1.33	60	2.00
25	.50	37	.89	49	1.38		
26	.53	38	.92	50	1.42		

89. To run Lines with the Solar Transit. — Having prepared a table of declination settings, set up the instrument over the point, get the telescope in the meridian by the method that applies to the instrument used, then loosen the alidade and direct the line of sight to some point in the line; the reading of the limb will give the required bearing (or azimuth) with the true meridian.

90. Merits and Defects of Solar Instruments. — The day for the use of the *solar compass* has passed. Though it is possible to do more accurate work with it than with the needle-compass, it is not likely that it will be more accurate, owing to the many precautions that must be observed. Instead of the solar compass, the transit, with or without a solar attachment, should be used.

No solar instrument should be used within an hour of sunrise or sunset, or within an hour of noon.

The ordinary solar compass and solar attachments without the solar telescope cannot be used in cloudy weather. Herein lies one important superiority of Saegmuller's attachment,* for it can be used in hazy and cloudy weather, provided the clouds do not entirely obscure the sun's disk. Other advantages are its simplicity, the ease with which it may be adjusted, and its precision.

* And other forms having a solar telescope.

THE Y-LEVEL

91. There are many kinds of levels, differing more or less in precision and cost. The so-called "Dumpy Level" is one of the simpler and cheaper varieties. Locke's Hand Level, which is not mounted on a tripod, but is held in the hand, is extensively used for rough preliminary work in seeking a location for a railroad.

The Drainage Level, the Architect's Level, etc., are manufactured for special use, as their names imply. A transit with vertical arc

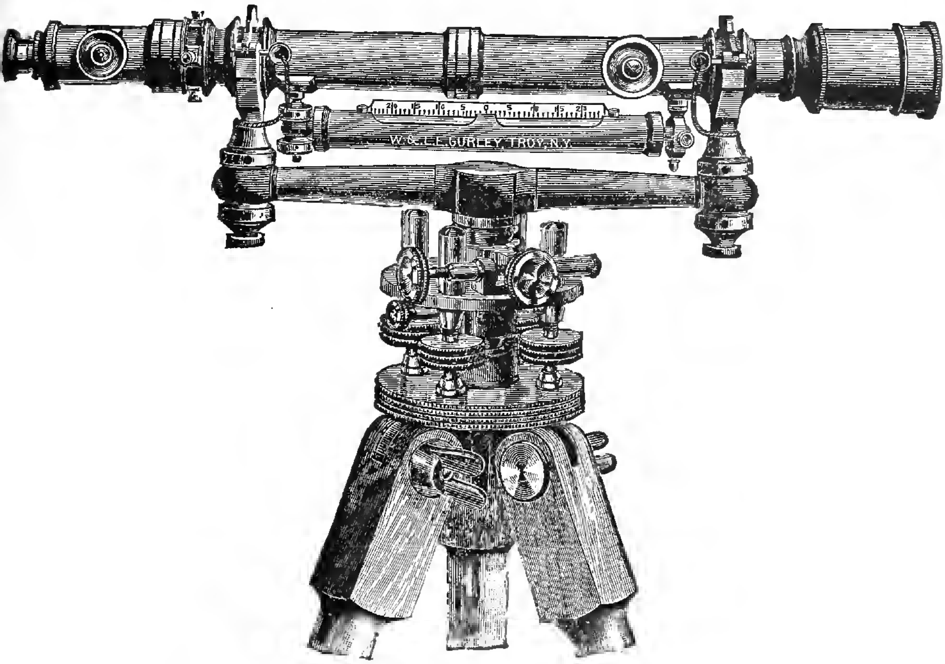


Fig. 19.—Y-Level

and telescope-bubble attached can be used as a level for any work ordinarily required of the surveyor. For more exact work the Y-level is the favorite instrument, though this is giving way to other forms of precision levels.

92. The Engineer's Y-Level consists essentially of a telescope properly supported on a spindle which revolves in a hollow cylinder attached to the leveling-head, which in its turn is supported by a tripod. Our cut represents a 20-inch Y-level, a sectional view of which is given on page 44. The telescope has near its ends two rings of bell-metal, turned very truly and of exactly the same

diameter. On these rings it revolves in the Y's (so called from their shape), or it can be clamped in any position, when the clips of the Y's are brought down upon the rings, by pushing in the tapering pins. The telescope-bubble is attached to the under side of the telescope, its ends being made movable for the purposes of adjustment. The leveling-head has the same plates and leveling-screws described in the account of the transit.

92 a. Parallax is the apparent motion of the cross-wires about the image of the object sighted at, as the eye is moved behind the eye-piece, and is due to lack of coincidence of cross-wires and image. It is overcome by focussing the eye-piece on the cross-wires so that they appear most distinct, and by bringing the image into focus by means of the objective.

To adjust * for parallax when using a level or transit, proceed as follows:

Throw objective out of focus or direct telescope to sky. Move eye-piece in and out till the position that gives the most distinct vision of the cross-wires is found. Then bring image into focus by means of the objective. Test adjustment by shifting the eye behind the eye-piece, observing whether there is any apparent movement of cross-wires about the image. This adjustment depends upon the eye of the observer. Another person, having eyes of a different focal range, would have to readjust the eye-piece. The adjustment, or focussing, of the objective depends on the distance of the object from the instrument, and must be made whenever a sight on an object at a different distance is taken.

92 b. For a remark on the general subject of adjustments, see Art. 55. A Level should always be kept in good adjustment, though errors of adjustments may be eliminated by making the *plus* (or back) sights equal to the *minus* (or fore) sights.

In ordinary work the leveler can usually tell by the behavior of the instrument when it requires adjustment. If the bar or bubble-tube is out of adjustment, the bubble will not remain in the center as the telescope is revolved. If elevations are taken on two points, first with equal sights and then with very unequal sights, any appreciable error in the adjustments will become apparent.

* This is not, properly speaking, an adjustment.

ADJUSTMENTS OF THE Y-LEVEL

93. First. — *To make the Line of Sight Parallel to the Axis of the Bubble.*

This adjustment may be divided into two parts:

(*a*) *To adjust the Line of Collimation.* — Set the tripod firmly, as in all adjustments, remove the Y-pins from the clips so as to allow the telescope to turn freely, clamp the instrument to the leveling-head, and by the leveling and tangent screws bring either of the wires upon the clearly marked edge of some object, distant from one hundred to five hundred feet. Then, with the hand, carefully rotate the telescope halfway round, so that the position of the same wire is compared with the object selected.

Should it be found above or below, bring it halfway back by the capstan head screws at right angles with it, always remembering the inverting property of the eye-piece; bring the wire again upon the object and repeat the first operation until it will reverse correctly. Proceed in the same manner with the other wire until the adjustment is complete. If it should be found that both wires are much out, it will be well to bring both nearly correct before either is entirely adjusted.

When this is effected, unscrew the covering of the eye-piece centering screws and move each pair in succession, with a screw-driver, until the wires are brought into the center of the field of view. The inverting property of the eye-piece does not effect this operation and the screws are to be moved as it *appears* they should be.

To test the correctness of the centering, rotate the telescope and observe whether it appears to shift the position of an object. Should any movement be apparent, the centering is not perfect.* When the centering has once been effected, it remains permanent, the cover being screwed on again to protect it from derangement.

(*b*) *To make the Axis of the Bubble Parallel with the Bearings of the Y-Rings.* — There are two methods of making this adjustment in common use. The better method is the so-called "Peg adjustment." For this see Art. 69, page 25. The other method, which is not so accurate but takes less time than the peg adjustment, is as follows: Bring the bubble into the middle with the leveling-screws, and then,

* In all telescopes the line of collimation depends upon the relation of the cross-wires and objective, and therefore the movement of the eye-piece does not affect the adjustment of the wires in any respect.

without jarring the instrument, take the telescope out of the Y's and reverse it end for end. Should the bubble run to either end, lower that end, or, what is equivalent, raise the other by turning the adjusting-nuts on one end of the level until, by estimation, half the correction is made. Again bring the bubble into the middle by the leveling-screws, and repeat the whole operation until the reversion can be made without causing any change in the bubble. It would be well to apply the second adjustment (Art. 94) before this adjustment is entirely completed. The adjustment just given may be called the reversal method. The peg method is the most exact, as the bubble is adjusted to an accurately established horizontal line, whereas in the reversal method it is assumed that the axis of the Y's and telescope are parallel, which may or may not be true.

94. SECOND. — *To bring the Axis of the Bubble into the Vertical Plane through the Axis of the Telescope.*

Clamp the instrument over either pair of leveling-screws, and bring the bubble into the middle of its tube. Turn the telescope back and forth in the Y's. If the bubble remains in the middle, no adjustment is necessary. If not, bring the bubble halfway back by means of the lateral adjusting-screws. Test by repetition. If this adjustment is much in error, it should be made approximately right before making the first adjustment.

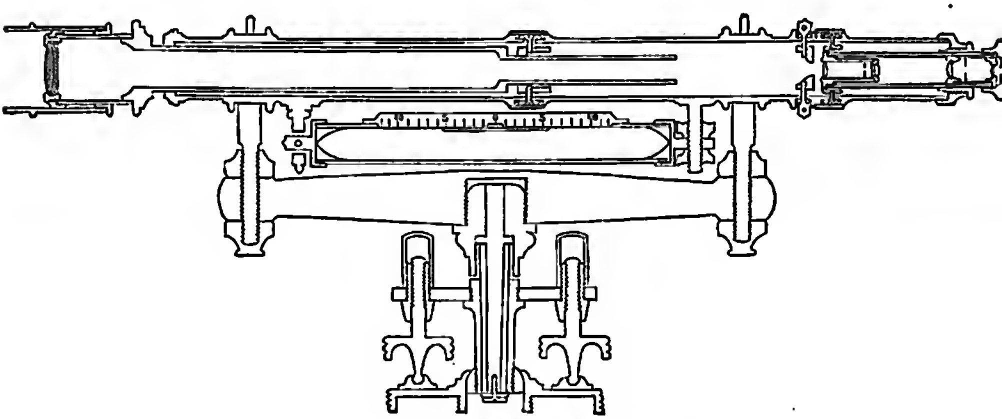


FIG. 20. — Sectional View of Y-Level

95. THIRD. — *To make the Axis of the Y's Perpendicular to the Vertical Axis of the Instrument.*

This is to enable the telescope to be revolved horizontally without re-leveling. Having placed the telescope over two of the leveling-screws, level the instrument. Revolve 180° horizontally, and correct one-half the movement of the bubble by the Y-nuts on either end of the bar, and the other half by the leveling-screws. Repeat for a check.

The first adjustment is by far the most important.

The use of the level will be explained in the chapter on Leveling.

LEVELING-RODS

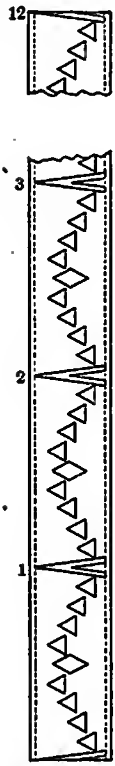
96. There are many forms of leveling-rods. It is very important that a rod be made of hard, well-seasoned wood that will not warp and will not easily wear. The graduations should be well defined and accurately placed. There are, in general, two kinds of leveling-rods: the Self-reading, or Speaking, and the Target Rod.

A *Self-reading*, or *Speaking*, *Rod* is one so graduated that it may be read directly by the observer who is handling the instrument. A *Target Rod* is furnished with a sliding target, which is set by the rodman in response to signals made by the observer. After the target is set so that its zero is in the line of sight of the telescope, its reading is recorded by the rodman. If a speaking rod is used, the observer records the elevation of the line of sight.

97. Figure 21 represents a target rod, called the New York Rod. This rod is made in two parts, sliding upon each other, and is graduated to tenths and hundredths of a foot. The rod is sometimes made in three or four parts, though two are more common. The front surface, on which the target moves, reads to $6\frac{1}{2}$ ft. on the two-part rods. When a greater height is required, the horizontal line of the target is fixed at the highest graduation, and the upper half of the rod carrying the target is moved out of the lower, the reading being then obtained by a vernier up to an elevation of 12 ft. This vernier and a similar vernier on the target itself enables the rod to be read to thousandths of a foot. The target is provided with a clamp for making it fast to the rod.

Fig. 21

98. *Self-reading Rods* are particularly desirable for use in stadia work. If the sights are not too long and the observer's eyes are good, a self-reading rod may give results that are almost, if not quite, as accurate as target readings. Figure 22 represents a stadia rod that the author had made for the use of his engineering classes. It is modelled after a design used by the United States Coast and Geodetic Survey,* with two slight changes in the graduations that seemed desirable.† The solid portions of the symbols are painted red on a white background. Here the principle of the triangle is employed to assist the eye in subdividing the graduations. Most self-reading leveling-rods are better for short than for long sights, but stadia rods are frequently read at long distances. The engineer can easily make his own rod, to be used for stadia work or as a self-reading leveling-rod. The one represented in our cut was a board 5 in. wide, 12 ft. long, 1 in. thick, stiffened by a strip screwed on the back.



Stadia Rod
Scale 1ft. to 1 in.
FIG. 22

THE PLANE-TABLE

99. The plane-table is extensively used for topographical and map drawing. It is a very satisfactory and convenient instrument for filling in the details of a topographical survey, based, as is usually the case, on a rigid system of triangles established by the transit. It consists essentially of a drawing-board upon a firm tripod, having upon its upper surface an alidade provided with either a sight-vane or telescope attached to a ruler. The telescope has a vertical motion like the telescope of a transit, but it has no lateral motion with respect to the ruler. The whole alidade may be moved at pleasure on the board. The details of construction vary considerably. The board is made to turn freely in azimuth. The plane-table represented in our cut has three leveling-screws and a tangent movement in azimuth. The board is partially cut away to show the details. A square brass plate with two bubbles at right angles and a needle-compass is furnished for the purpose of leveling the table and determining the magnetic bearing of the lines. This table has an adjustable wooden roller

* See Baker's "Instruments."

† Here the graduations are so arranged that in any position the cross-wire will have some white field behind it.

at each end by which the paper is brought down snugly to the board or upon which a long sheet can be rolled and unrolled at will. Sometimes brass clamps are used to fasten the paper to the board. The plumbing-arm shown in the figure determines the point on the ground corresponding to a given point on the paper.

The surveyor familiar with the adjustments of the transit, as already given, will have no difficulty in adjusting the plane-table.

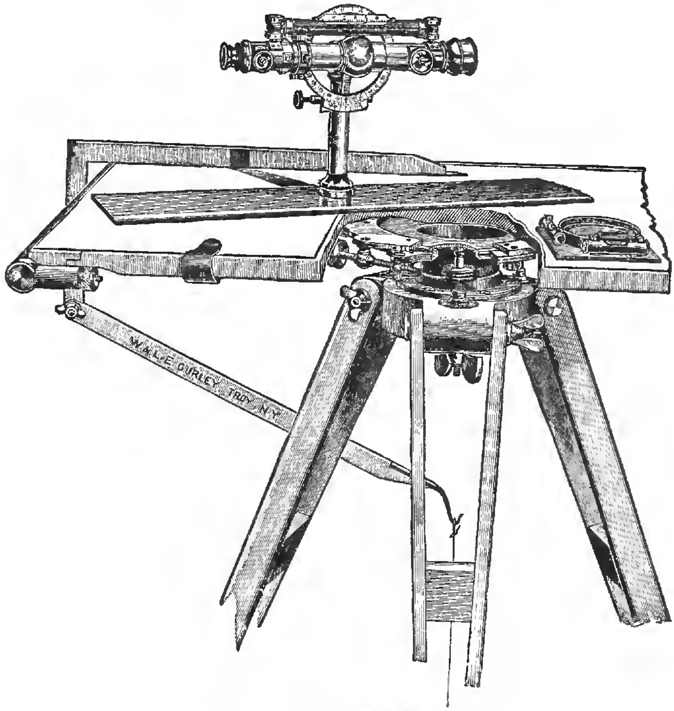


FIG. 23.—Plane-Table

THE USE OF THE PLANE-TABLE

100. In the area to be surveyed by means of the plane-table, it is necessary that at least two points and the distance between them be accurately known beforehand, and the points marked on the ground. It is preferable that all the other points be visible from each of the two given points, if the method of locating them by intersecting lines be used. Suppose now, for illustration, that A and B are the two known points, the distance AB having been carefully measured. Having snugly secured to the board a sheet of drawing-paper, represented in Figs. 24 and 25 by TT', plot on the paper the line

$ab = AB$, using the scale to be adopted in the drawing. Set up the plane-table so that a shall be directly over the point A and level it. Then place the fiducial edge of the ruler along the line ab with the telescope pointing toward b, Fig. 24. Orient the table (that is, revolve it in azimuth) till the telescope points to B, bisecting the point by aid of the tangent screw. Keeping the board clamped, move the alidade around a as a pivot (that is, a must be kept on the fiducial edge) until the telescope points to C, then draw an indefinite line ac'; c (representing C) will be somewhere on this line. In the same way, the other points are sighted, and the indefinite lines ae', af', ad' drawn. Here A, B, C, D are the corners of a quadrilateral, and E and F are a tree and a chimney, respectively.

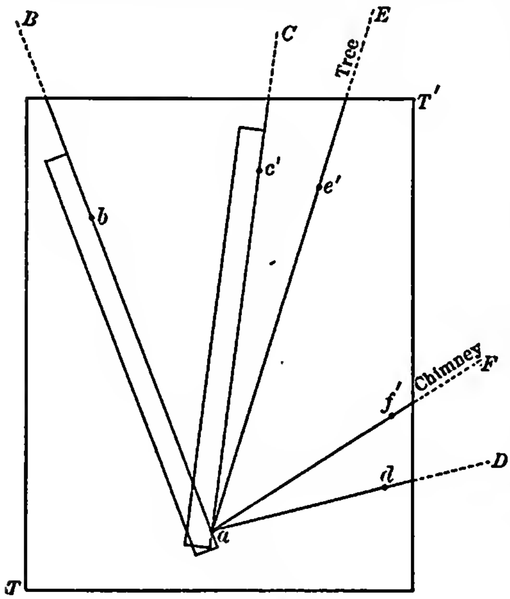


Fig. 24

Next move the instrument to the point B, set it up so that b is exactly over the point B, Fig. 25, and place the alidade so that the fiducial edge of the ruler is along ba, the telescope pointing toward a. Then orient the plane-table till the line of sight bisects a pole held on A. Then, keeping the board clamped, move the ruler around b

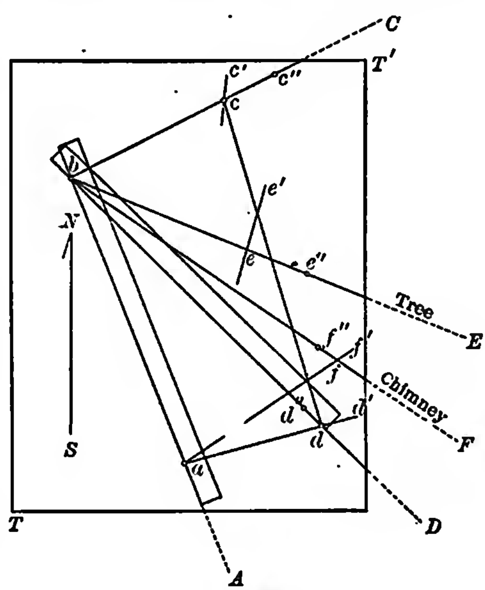


Fig. 25

(just as before it was moved around a) until D is bisected by the line of sight. Draw the line bd'', or that portion of the line that intersects ad', thus determining the intersection "d," which corresponds on the drawing to the point D. In turn, F, E, and C are sighted, and the intersections of bf'', be'', bc'' with af', ae', ac', respectively, are determined.

As a check on the work, one or more of the points thus found, say C, may be marked by a stake on the ground and the plane-table set up over that point, and in the same manner as before, the line cd may be drawn. This line should pass through the intersection of ad' and bd''. It is important to test the work in this way. It will be observed that in Fig. 24 the point A is covered by a, and in Fig. 25 the point B is covered by b. It is best to draw only such portions of the radiating lines as are necessary to determine the intersections. Notes furnishing full explanations of what objects are located by the lines should be kept in a note-book.

The telescope is usually fitted with stadia wires. If the distances are measured by the stadia (see Chapter V), as is commonly done, an object may be determined by a single pointing, the distances being plotted off to scale on the proper lines.

Many problems may be solved by the plane-table. For a fuller description of the instrument and its use, the reader is referred to an article on the plane-table in the report of the United States Coast and Geodetic Survey for 1880, Appendix 13.

THE SEXTANT

101. The *sextant* is the most convenient and the most accurate hand instrument for measuring angles. It is invaluable to the mariner for use on board ship, where none of the instruments that we have described can be used. It is extensively used on boats in the survey of harbors, the location of buoys, etc. It is sometimes used by the surveyor in preliminary surveys on land. The theory of the sextant presents no difficulties. It is called a "sextant" because an arc of 60° is used in measuring angles.

DRAWING INSTRUMENTS

102. For the purpose of plotting, the surveyor needs only a few simple instruments whose use can be readily learned. The following list will, in most cases, be all-sufficient:

A drawing-board.
One triangle, 90°, 60°, 30°.
One triangle, 90°, 45°, 45°.
A T-square, a triangular scale.
A protractor.
A drawing-pen.
A pair of dividers, with pen and pencil points.
A hard pencil, erasing-rubber, and some thumb-tacks.

103. A convenient size for the drawing-board is 23×31 in. Occasionally a larger board will be desirable. Well-seasoned pine wood is the best material.

The *triangles*, which are made of hardwood, india rubber, and other material, give at once the simplest and most reliable method

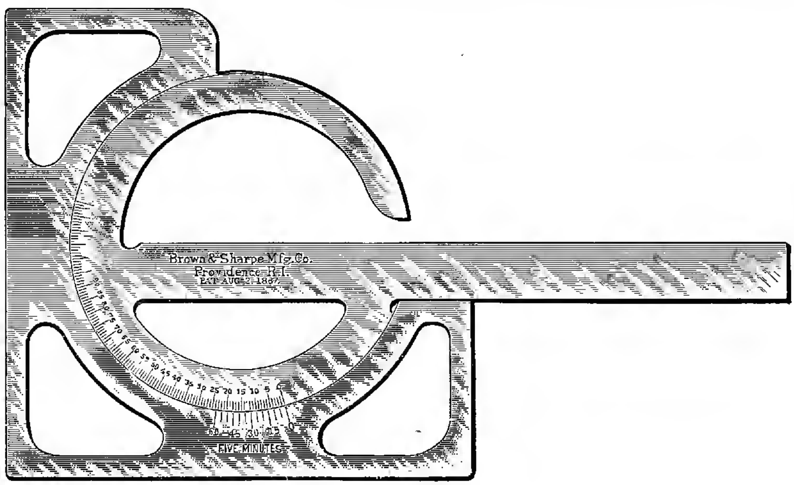


FIG. 26. — Protractor

of drawing parallel and perpendicular lines, for which purpose they are chiefly used. The hypothenuse should be from 10 to 14 in. long. The two are used together, or in connection with a T-square.

The T-*square* should be 2 ft. long.

The *triangular scale* should be graduated decimally,* and should be 12 in. long.

This rule has six edges, giving a choice of six scales, the smallest graduations being $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{30}$, $\frac{1}{40}$, $\frac{1}{50}$, $\frac{1}{60}$, of an inch respectively. It is laid on the paper, and distances to the chosen scale are marked off directly from it. It is far more convenient than the old flat diagonal scale, which required distances to be taken off with the dividers and transferred to the paper.

* Architects and machinists prefer a scale of so many inches, halves, quarters, eighths, etc., to the foot.

104. Protractors. — The protractor is an instrument for measuring angles, and is made of metal or paper, usually in the form of a semicircle. The common brass or german silver protractor, 4 to 6 in. in diameter and graduated to half-degrees, is of very little value. Paper protractors, 12″ to 14″ in diameter, are much better, and also cheaper. Where very accurate work is desired, a higher grade protractor, with movable arm and vernier reading to 1 or 2 min., should be used. Such a protractor costs from $12 up. A very convenient and reliable steel protractor, which sells for $6.50, is represented in our cut, Fig. 26.

105. To use the Semicircular Protractor. — Suppose it is required to lay off the bearing of AB = N. 35° E., and the bearing of BC = S. 60° 30′ E., Fig. 26_a.

Lay off on a sheet of paper, sufficiently large to contain the drawing to the chosen scale, a north and south line NS, through

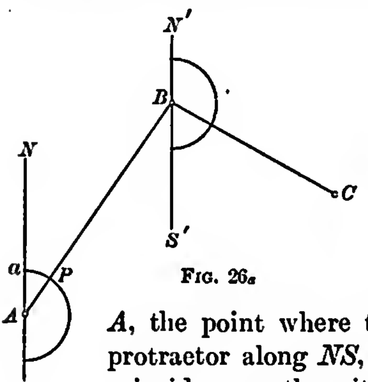
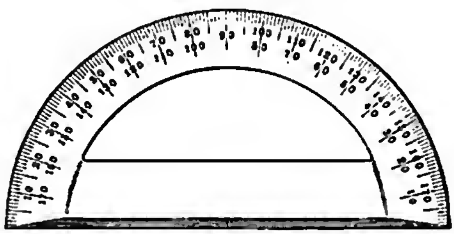


Fig. 26_a



A, the point where the line is to begin. Then place the protractor along NS, as in the figure, so that its diameter coincides exactly with NS, its centre being at A. Now count off 35° from a to P, and at the 35° mark make a dot on the paper at P. AP continued to B will be the required line, which should be drawn to the proper linear scale. Move the protractor to B, place it as before, but this time count the angle 60° 30′ around from the south point.

EXERCISES

1. Measure a line on fairly level ground, from 10 to 20 chains in length. Remeasure it in opposite direction and note the difference in results, if any.

2. Measure a line of about the same length on very hilly ground. Remeasure it as before and note the difference in results.

3. Lay out on a stretch of level ground the length of a standard chain, carefully marking the ends by a line cut in a rock or by a tack in the top of a wooden stake. Compare the length of any chain or tape that is accessible with the standard thus obtained.

4. If the length of a line measured with a Gunter's chain that is .5 of a link too long is found to be 10.56 chains, what is its true length?

5. If the chain of the last example is used in measuring the boundary of a field that is found to contain 40 A., what is the true area of the field?

6. If a field is found to contain 30 A. when a chain one link too short is used, what is the true area?

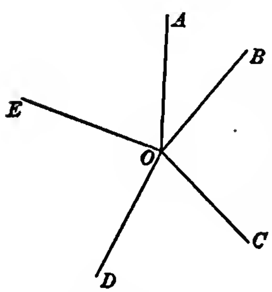
7. On hilly ground measure a line horizontally, for example, the line of Example 2; then measure the same line, allowing the chain to rest on the slope of the ground, and note the difference.

8. Adjust a needle-compass.

9. Adjust a Y-level.

10. Adjust a transit.

11. Adjust a Saegmuller attachment.



12. Set a needle-compass over a point O, in view of the five points A, B, C, D, and E; get the bearings of OA, OB, OC, OD, and OE; compute from these bearings the angles AOB, BOC, COD, DOE, and EOA, and add these angles together. Does their sum equal 360°?

13. Set up a transit over the same point O, and measure the horizontal angles. Add them together and compare their sum with 360°.

14. Establish three stations forming a triangle. Measure the horizontal angles with the transit and see if their sum is equal to 180°.

The above problems are merely suggestive. They may be multiplied indefinitely.

CHAPTER II

CHAIN SURVEYING

In the absence of an instrument for measuring angles, effective work can be done with simply the chain and ranging poles.

106. To range out a Line.—This can best be done by three persons, whom we shall call A, B, and C, each with a ranging pole. A and B take their positions on the line, not too close to each other; C goes forward and puts his pole in line with A and B; then A advances beyond C and puts his pole in line with B and C; then B advances and sets his pole beyond A in line with C and A; and so on.

107. Over a Hill.—Suppose it is required to range out a line from P to Q, a hill intervening so that one cannot be seen from the other.

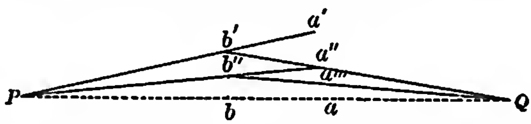


Fig. 27

Let two men, A and B, each with a ranging pole, select two points approximately between P and Q, one on the slope of the hill toward P, the other over the brow toward Q, and both visible from P and Q. Let A, from his position at a', motion to B till he puts him in line with P, at b'; then B, at the point b', puts A in line with Q; again A, being now at a'', puts B in line with P; next B, in his turn, puts A in line with Q. This operation is continued until the poles are at a and b, in line with P and Q.

108. Through a Wood.—In chaining through wood or brush, where one end of a course cannot be seen from the other, it is often best to measure a second line, as near to the first as convenient, but avoiding trees. Suppose that the line AB is more or less obstructed by trees, but that a line AD, free from trees and making

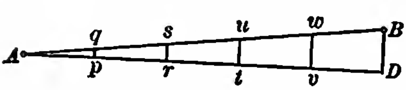


Fig. 28

a small angle* with AB, is ranged out and measured. When this has been done, DB is measured and AD is divided into a convenient number of parts. At the points of division, the lines pq, rs, . . . are supposed to be drawn parallel to DB.

The offsets pq, rs, etc., are known by proportion. Measure these offsets approximately parallel to DB and plant stakes, which will be on the required line AB. For example, if $DB = 12.5$ ft., $AD = 500$ ft., and $Ar = 200$ ft., then

$$rs : BD = 200 : 500.$$

$$\therefore\ rs = \tfrac{2}{5}\,BD = 5 \text{ ft.}$$

109. To erect a Perpendicular at Any Point in a Line.

(*a*) First Method. — From the given point A, in the line OX, lay off, with the chain along OX, $AC = AB$. At B and C as centres, with a radius considerably greater than AC, say one chain-length, describe arcs cutting each other at E. Then EA will be perpendicular to OX. Why?

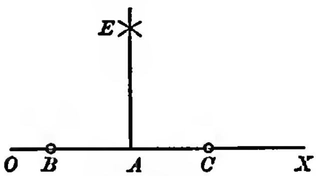


Fig. 29

(*b*) Second Method. — Hold one end of the chain at the point A. Let an assistant stretch the chain along AO and hold the end of the 20th link exactly on the line AO, at B. Let another assistant count off 60 links from A, hand the end of this 60th link to the man at A, and catching the chain at the end of the 45th link (from A), stretch it until both parts are taut — OE (25 links) and AE (15 links) in the diagram. Then evidently, as $25^2 = 20^2 + 15^2$, OAE is a right angle and AE is perpendicular to OX. Of course we are not restricted to the combination 20, 25, 15, as we simply have to choose three numbers such that the square of one is equal to the sum of the squares of the other two.

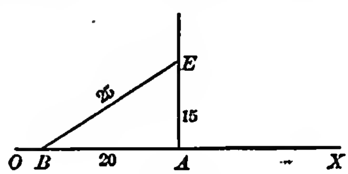


Fig. 30

(*c*) Third Method. — Hold one end of the chain at A, and fix the other end at some point, C, then with C as a centre swing the chain around till the end strikes the line OA at E; mark the point E, and, still holding the end at C, swing the chain around till it

* If the angle is large, the chances for error are greater.

reaches B, in line with EC; then AB will be the required perpendicular, for the angle A being inscribed in a semicircle is a right angle.

This method is convenient if some obstacle prevents the extension of the line beyond A, especially if the perpendicular passes through a building or over a stream.

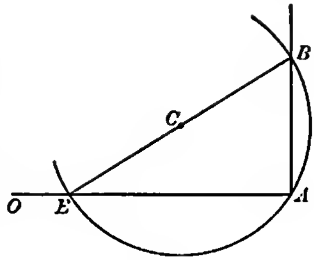


Fig. 31

110. To let fall a Perpendicular from a Given Point to a Given Line.

(*a*) First Method. — If the point is within a chain's distance of the line, with the chain as a radius and A as centre describe an arc cutting OX at B and C. Find the middle point E of BC, and then AE will be the perpendicular required.

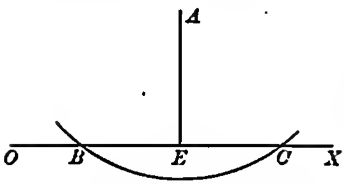


Fig. 32

(*b*) Second Method. — The principle of the third method of Art. 109 may be employed. Let the student show how this may be done.

111. To let fall a Perpendicular to a Line from an Inaccessible Point. — Let P be the point, OX the line. At any point A on the given line erect a perpendicular AB and prolong it below the line, making $AC=AB$. Find the point D on the line OX in line with PB and the point E in line with PC. Draw BE and prolong it to meet DC in F; then FP will be the required perpendicular.

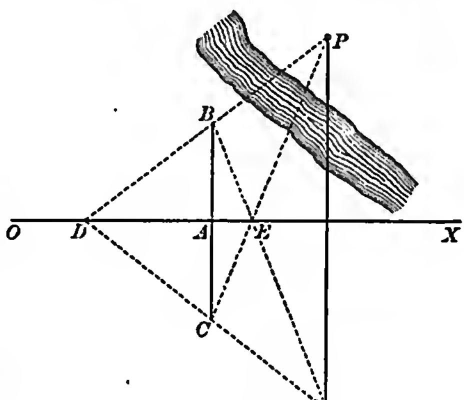


Fig. 33

112. To run a Line through a Given Point Parallel to a Given Line. — Let P be the point and AB the line. From P draw PD perpendicular to AB, and at some other point, B, of the line erect a perpendicular BE and make it equal to PD. PE will then be the required line parallel to AB.

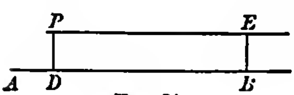


Fig. 34

Or, from P (Fig. 35) draw the oblique line PB terminating in the line AB, and find its middle point M. From some other point of the line AB, as C, draw CM and prolong it to E, making $ME = CM$. Draw PE. It will be the required line parallel to AB.

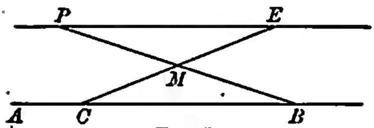


Fig. 35

The solution of the problem in the next article furnishes another method.

113. To construct an Angle Equal to a Given Angle. — Let ABC be the given angle. Suppose it is required to draw from the point E a line making with EX an angle $= ABC$.

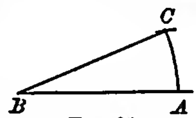


Fig. 36

From B as a centre with some convenient radius, as a chain-length, describe the arc AC; that is, determine the two points A and C. Measure the distance AC. Then from E as a centre with the same radius describe an arc DG, and from D as a centre, with radius $= AC$, describe an arc intersecting DG at F. Draw EF; then DEF will be the angle required.

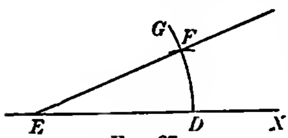


Fig. 37

Or, if the angle is given in degrees, and the surveyor has at hand a table of chords, the method explained in Art. 166 may be advantageously employed.

OBSTACLES TO ALINEMENT AND MEASUREMENT

114. One method for prolonging a line beyond an obstacle has already been given in Art. 108. Our diagram, Fig. 38, shows a second method.

At two points, A and B, on the line to be prolonged erect perpendiculars AE, BF, and make them exactly equal. Prolong EF, and at two points on it beyond the obstacle, such as G and H, erect perpendiculars GC and HD equal to AE; then CD will be on AB prolonged. If the distance is wanted, measure FG, which is equal in length to BC.

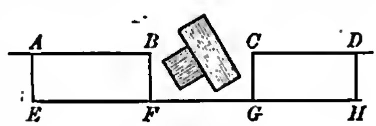


Fig. 38

115. Third Method. — By equilateral triangles.

Taking AB on the given line as one side, construct an equilateral triangle ABC. Prolong AC to D a sufficient distance to pass

the object; lay off the equilateral triangle EDF, prolong DF till $DG = AD$; at G construct an equilateral triangle GKH; then KG will be on the prolongation of AB.

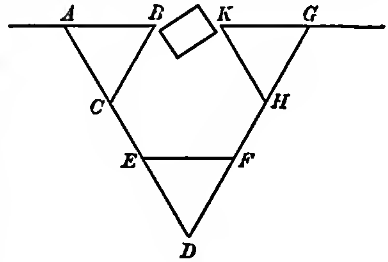


Fig. 39

A convenient way of constructing an equilateral triangle is as follows: Lay off on the line the distance $AB = 33$ links; hold one end of the chain at B and also the end of the first link at other end of the chain at B; fix the end of the 33d link at A, take hold of the 66th link and pull the chain till both sides are taut; this will give the vertex C of the equilateral triangle. If the distance as well as the alinement is wanted, the measure of AD gives also the length of AG.

Other methods of passing an obstacle will readily suggest themselves to the thoughtful student.

116. Nearly all of the above problems can be solved more simply and with greater accuracy with an instrument for measuring angles, such as the transit. The solutions are so similar that it will not be considered necessary to repeat these problems in the chapters on Compass and Transit Surveying.

117. Areas. — With the chain alone one can make all measurements necessary for obtaining the areas of plane figures, such as triangles, parallelograms, and regular polygons in general, though in most cases it is advisable to use also a compass or transit, if such an instrument is available. An examination of the formulæ on page 95 will show the student what measurements must be made in order to get the area of fields of simple, regular shapes. Some problems are given in another place. His college campus, ball-ground, or lots in the neighborhood will furnish other examples.

HEIGHTS

118. To determine the Height of a Church Spire, Tree, or Other Object. — On a clear day measure the shadow of a 10-foot pole and the shadow of the object whose height is sought. The proportion

Length of shadow of the pole : 10 ft.

= length of shadow of the tree : height of the tree,

gives the height of the tree in feet.

In the absence of an angle measurer, this method gives an approximate result. Or, the height may be found by using a transit. Suppose the height of a tower BA, Fig. 40, is required. Set up the transit at some point E, preferably about as far from the foot of the tower as the top of the tower is from the ground. Measure the angle of elevation DCA; then AD is found by the formula $AD = CD \tan DCA$, and $AB = AD + DB$. CD is the line of sight, and DB is exactly equal to the height of the instrument, CE but only when the ground EB is level.

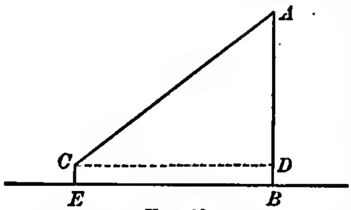


Fig. 40

EXERCISES

1. Given a point near a building, mark the point on the foundation of the building exactly opposite* the given point; that is, determine the perpendicular from the given point to the line of the building.

2. Determine a point 90 ft. from the front wall of a house, and directly opposite the middle point of the wall.

3. Through the point thus determined range out a line parallel to the house.

4. Lay off the foundation of a house, 50 ft. by 30 ft., the longer side being parallel to a straight road and 300 ft. distant from it.

5. Measure carefully the dimensions of a large house of irregular plan, or of a group of houses. In a near-by field, lay out the foundation of a similar house or group of houses.

6. Select a line that intersects a house, and prolong it beyond the house by at least two methods.

7. Stake out a triangle ABC, measure the three sides and compute its area (Table XII). Using the same triangle, drop a perpendicular from C on AB; measure the perpendicular and the side AB, and compute the area of the triangle (Table XII).

8. A field in the shape of a trapezoid has its parallel sides equal to 20 ch. and 18 ch., and the perpendicular distance between them 11 ch. What is its area?

* Beware of the very common but loose use of the word "opposite." The last part of the statement of our problem defines the term as here used.

9. The length of a rectangular field containing 10 A. is double its breadth. Find its dimensions in chains; also in feet.

10. A circular field contains 61,600 sq. ft.; what is its radius? (Let $\pi = \frac{22}{7}$.)

11. What is the length of the side of a square field containing one acre?

12. Lay off a lot in the shape of a hexagon, whose side equals 1 ch. What is its area?

13. The sides of a field *ABCDEFGHA*, Fig. 41, were measured; then the diagonals *BD*, *BG*, *AG*, *GD*, were ranged out and measured; next the perpendiculars *Bl*, *Ci*, *Gk*, *Hm* were determined. It was found that *DEFG* was a square. Compute the area of the entire field, using the following values, distances being given in chains:

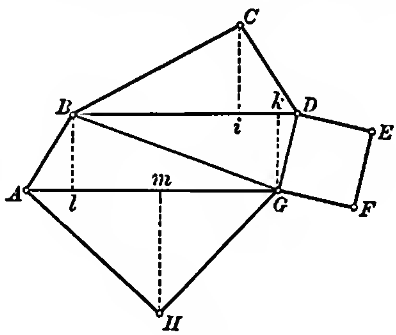


FIG. 41

$AB = 9$	$FG = 8$	$Bl = 7.80$
$BC = 20$	$GH = 18$	$Ci = 9.40$
$CD = 11$	$HA = 19$	$Gk = 8.00$
$DE = 8$	$BD = 23.50$	$Hm = 13.00$
$EF = 8$	$AG = 26.23$	

14. Using the chain alone, make a survey of a field of irregular shape, as in the last example, and compute its area.

CHAPTER III

COMPASS SURVEYING

I. FIELD OPERATIONS — ORIGINAL SURVEYS AND RE-SURVEYS

119. We have seen in Chapter I that the bearing of a line as obtained by the needle-compass is an uncertain quantity, owing to the variation in the declination of the needle. It is not easy to read the needle within 5 min., and, even if it were possible to do so, it cannot be relied upon to give an angle with a probable error as small as 5 min. But, notwithstanding its manifest defects, the needle-compass is a most useful instrument because of its simplicity and the rapidity with which it can be used.

In Art. 59 we have seen how the magnetic bearing of a course is obtained. At the outset the following problem is important:

To determine the angle between two courses whose bearings have been found.

120. First Case. — *When the courses are run from the same angular point.*

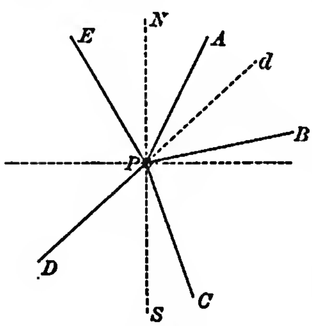


Fig. 42

(*a*) Given:

bearing of PB = N. 78° E.,

bearing of PA = N. 25° E.,

to find the angle APB.

If NS, Fig. 42, is the north and south line, it is evident that

$$APB = NPB - NPA = 78° - 25° = 53°.$$

So in this case we simply subtract the bearings.

(*b*) Given: bearing of PC = S. 20° E.,

bearing of PB = N. 78° E.,

to find angle BPC.

Here $$BPC = 180° - (NPB + SPC)$$
$$= 180° - 98° = 82°.$$

(c) Given: bearing of PA = N. 25° E.,
bearing of PD = S. 48° W.,

to find angle APD (less than 180°).

Produce DP back to d; then,

$$NPd = SPD = 48°, \text{ and}$$
$$APd = NPd - NPA = 48° - 25° = 23°, \text{ and}$$
$$APD = 180° - APd = 180° - 23° = 157°.$$

(d) Given: bearing of PA = N. 25° E.,
bearing of PE = N. 30° W.,

to find angle APE.

$$APE = 25° + 30° = 55°.$$

It is obvious that rules could be framed for all four cases and for those that follow; but it is a better plan for the student to solve any such problem by aid of a diagram until he knows the principle so well that he can solve the problem mentally with very little likelihood of an error.

121. Second Case. — *When the courses are run in the ordinary way as we go around the field.*

In going around a field $ABCDA$, suppose we have the bearings of the sides given, to find the interior angles.

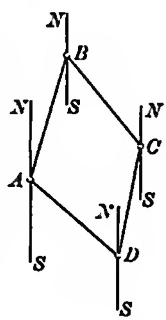


Fig. 43

(a) Given: AB, N. 15° E., BC, S. 40° E., to find angle ABC.

Since $SBA = NAB$, $ABC = 15° + 40° = 55°$.

(b) Given: BC, S. 40° E., CD, S. 10° W., to find angle BCD.

Here $BCD = 180° - (40° + 10° = 130°)$.

(c) Given: CD, S. 10° W., DA, N. 50° W., to find angle CDA.

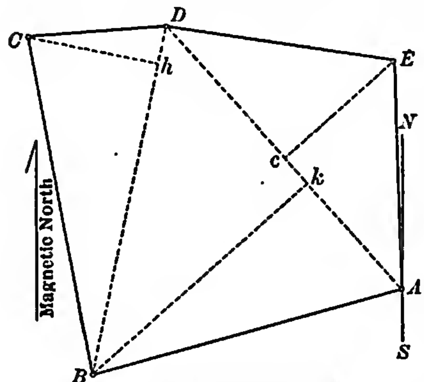
$$CDA = 10° + 50° = 60°.$$

(d) Given: DA, N. 50° W., AB, N. 15° E., to find DAB.

$$DAB = 180° - (50° + 15°) = 115°.$$

FIELD WORK

122. When a field is to be surveyed, we begin at some convenient corner and go entirely around it, taking the bearings of each side with the compass and measuring them with the chain or tape. It makes no difference whether the field is kept on the right or the left in going around it. In the example below, which is used for illustration, the field is on the right.



Declination of the Needle 0° 15′ E.
Scale 20 rds. to 1 in.
FIG. 44

Let *ABCDEA*, Fig. 44, be a field to be surveyed, *A* the corner where the work is to be begun, *NS* the direction of the magnetic meridian. The surveyor should be provided with a pocket field book, ruled with three columns on the left-hand page, the right-hand being reserved for remarks. In the first column is given the number of the station (indicated by letter or numeral); in the second, the bearing; and in the third, the distance. Some prefer to put in the station column "*A* to *B*," "*B* to *C*," etc., where we put simply "*A*," "*B*," etc.

The bearings in parentheses, in smaller type, are the back-sights, or reverse-bearings. A back-sight should always be taken as a check on the first reading; often it also brings into evidence local attraction, or some imperfection of the needle. A back-sight should *be equal numerically* to the fore-sight and differ from it only in the two letters by which it is designated. For example, the back-sight from *B* to *A* should have read N. 75° 25′ E. It differed from this reading by 7 min., hardly enough to make us suspect local attraction. When a small difference like this is left uncorrected, the mean of the two readings should be adopted.

The field work may proceed as follows:

Having set up the compass over the corner *A* (if this point is accessible), level it, and then let the needle down upon its pivot. Sight a rod held at the next corner *B*, or at least somewhere on the line *AB*. After the needle has settled, the reading S. 75° 25′ W. gives the bearing of *AB*,* which is recorded as below.

* Remember that, if the south end of the compass-box is kept toward the observer, the bearing is always given by the *north* end of the needle.

Then AB is measured, and its length, 50.04 rd., is put down in the distance column.

Next, having raised the needle off its pivot, carry the compass to B, and set it up. First a back-sight is taken on a pole held at A. This reverse reading (N. 75° 32′ E.) is given in parentheses just above the bearing of the next course. Then a sight is taken on C, and the bearing of BC is found to be N. 10° W, which is duly recorded, as is the measured length of BC, 53.72 rd. On moving

Station	Bearing	Distance (rods)	Remarks
A	(N. 1° 20′ W.) S. 75° 25′ W.	50.04	To a stake.
B	(N. 75° 32′ E.) N. 10° W.	53.72	To point on rock.
C	(S. 10° E.) N. 86° 30′ E.	21.84	To white oak.
D	(S. 86° 40′ W.) S. 80° 30′ E.	35.92	To a stake.
E	(N. 80° 30′ W.) S. 1° 10′ E.	35.68	To cross in stone.

the instrument to the next station, C, the back-sight to B is found to be S. 10° E., which coincides exactly with the forward sight; thus the bearing and length of every course are found in order. Under the head of "Remarks" each corner should be described as accurately and concisely as possible. Much varied information often finds a place under the head of "Remarks." The surveyor should form the habit of jotting down any bits of information that may possibly throw some light upon the survey and be useful in making the plot or settling a disputed question at some future time.

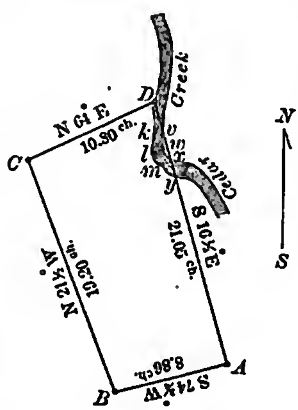


Fig. 45

The above method of keeping the field notes is the most compact and the best form to use in most cases, especially when the area is to be obtained by the double meridian distance method (see Chapter IV).

123. A very convenient method for keeping the notes when the shape of the field is not too complicated, especially if offsets are to be taken, is to make a rough diagram, as in Fig. 45, the various bearings

and lengths being recorded along the lines to which they belong. The distances Dv, Dw, etc., and the offsets would usually be written on these lines instead of below the diagram.

Between D and y the boundary of the field follows the bank of the creek.

$DA = 21.05$ ch.	$kv = 0.65$ ch.
$Dv = 2.48$ ch.	$lw = 1.20$ ch.
$Dw = 3.80$ ch.	$mx = 1.00$ ch.
$Dx = 4.88$ ch.	
$Dy = 6.20$ ch.	

There are other ways of recording the field notes. It matters not so much by what method it is done, provided it be done accurately and fully enough, so that the surveyor, in referring to his notes later, will have no doubt as to their exact meaning. Another method will be explained in Art. 127, where a general example is given.

124. The boundaries of fields are generally marked by fences, and it is seldom in settled countries that the compass can be set on the line, or that the chain can be carried on the line. In such cases it is necessary to take the bearing of a line parallel to the line whose bearing is sought, and to measure the distance by taking rectangular offsets, as shown in Fig. 46.

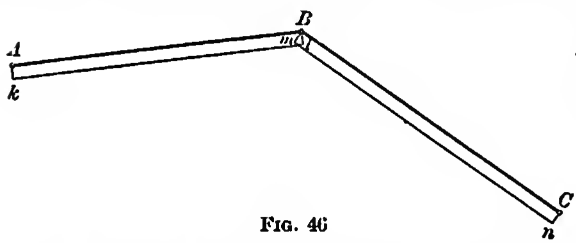


Fig. 46

If the bearing and length of AB, BC cannot be secured directly, owing to the presence of the fence, measure off at A and B, perpendicular to AB, the distances Ak and Bl of the same length (as a rule it is better not to go farther from the boundary than is absolutely necessary). Then set up the compass at k and a range pole at l; get the bearing of kl, which will be the bearing of AB, and measure the distance $kl = AB$. If there is an angle at the next corner, be careful to measure the new corner from m opposite B, and not from l. Observe that it matters not where the compass is set on a straight line to get the bearing.

125. Beside the regular variation in the declination of the needle local attraction is one fruitful source of error. Temporary, though serious, deflection has often been caused by an axe or chain held too close to the compass, by a bunch of keys in the pocket, or by the steel

frames of the surveyor's spectacles. Local attraction may be caused by iron ore in the ground, by an electric current in a wire, or by the proximity of a wire fence or some iron structure. The existence of local attraction is often revealed by the behavior of the needle.

126. To correct Local Attraction. — If the back-sights and fore-sights have agreed for several stations, and then one is found where they do not agree, it may be presumed that there is local attraction at the last point.

For example, suppose (Fig. 47)

bearing of AB = N. 20° W.,
back-sight at B = S. 20° E.,
bearing of BC = N. 30° E.,
back-sight at C = S. 28° W.

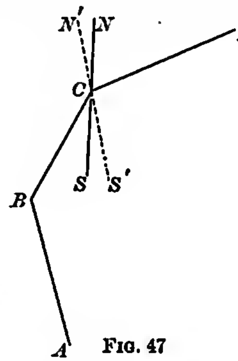


FIG. 47

Now, suppose the fore-sight at C to be N. 60° E., what is the correct bearing of CD?

Here, as the back-sight at B was equal to the fore-sight at A, we conclude that there is local attraction at C, which draws the north end of the needle east by *two* degrees, making it occupy the position NS instead of the true position $N'S'$. Hence the fore-sight of CD is too small by 2°, and the bearing should be N. 62° E. If, after moving the instrument to D, the back-sight there is found to be S. 62° W., our correction is verified, and the local attraction that existed at C is not present at D. If the back-sight at D does not coincide with the corrected fore-sight at C, we must test by the next corner in advance of D.

It sometimes happens that several adjacent corners are affected, and it may be impossible to get a consistent series of bearings without the aid of a transit or solar instrument.

127. *General Example.* — As illustrating the method of making a compass survey and recording the notes, we take an example of a farm, the plot of which (Plate II) is represented on page 68. For brevity we give only the notes locating the boundary lines, the turnpike, and one lane; but these are enough to suggest to the student the field work necessary to locate definitely the division lines, houses, etc. Here the field notes were entered from the bottom of the page up. It will be observed that in this survey the farm was kept on the left.

There is a station, represented by Δ, at each corner, the work beginning at "A," marked by a "stake south line R. R., east side of

	110		to stake, beginning.
	ΔH	N. 85° 10′ W.	along R. R.
	102.40		to stake on R. R. limits.
	72.41		stream.
	12.50	road	to sawmill.
	ΔG	N. 18° 52′ E.	
	100.75		to stone monument on bank of creek, 12 rods above sawmill.
	95	.50	
	90	2.04	
	80	4.20	
	70	6.70	
	60	8.10	
	50	7.82	offsets.
	40	7.30	Line follows bank of creek.
	35	6.40	
	30	8	
	20	12.32	
	10	6.21	
	ΔF	N. 44° E.	
	28.68		to stake on bank of creek.
	4		
Turnpike			
	ΔE	East	
	148.70		to stone on west side of turnpike.
		stream	
	114		
	ΔD	S. 86° E.	
	67.51		to stake near walnut stump.
	ΔC	South	
	145		to black oak.
	101.20	Smith-Allen corner.	
	ΔB	S. 30° 8′ W.	
	100		to a stake.
		stream	
	60.24		ΔA, stake south line of R. R., east side of turnpike, nearly opposite depot. Distances in this survey given in rods.
	4		
Turnpike			
	ΔA	N. 75° 50′ W.	
	$\Delta d'$		on DE.
	98		to line DE.
	$\Delta c'$	South	
	87		
	$\Delta b'$	N. 80° W.	$\Delta b'$ at Δb, foot of lane.

LANE

	Δc		on *EF*.
	89.40		to line *EF*.
	Δb	S. 2° 50′ E.	
	92.60	N. 80° W.	to stake, centre of pike opposite lane.
Sawmill			
	51.40		Bearing of road, S. 85° 15′ E.
Road			
	49		front gate.
	21		stream.
	Δa	S. 14° W.	Δa in centre of turnpike opposite ΔA.

TURNPIKE

turnpike, nearly opposite depot." The bearing of the course, *AB*, is N. 75° 50′ W., and its length is 100 rd. Along *AB* are noted the distance 4 to far side of turnpike (the width being 4 rd.), and 60.24, marking the point where a stream crosses the line. Notice that in this form of notes the distances read from the preceding station, and the last distance entered, immediately below the next Δ, gives the length of the course. The bearing of the next course, *BC*, is found to be S. 30° 8′ W., the distance along this course to the corner of the Smith and Allen farms, 101.20, is noted, and the entire length to the corner at the black oak, 145, is duly recorded; and so the work proceeds.

F is on the bank of Beaver Creek, and between *F* and *G* the boundary follows the bank of the creek. At convenient intervals along *FG*, every 5 or 10 rd., offsets are taken to the creek. These offsets enable us to plot the course of the creek, and by means of the trapezoids and triangles formed by them the area outside of *FG* is readily obtained.

On returning to *A*, the instrument is set up in the middle of the pike opposite "*A*," and the pike is run out, only two courses being required, as there is only the one bend. Here, on the first course, *ab*, the sawmill road is noted on the left, and the farm lane on the right, their bearings being taken and recorded. The private lane is also run out. Notice that the compass is not set over stations *c* and *d′*, unless it is desired to take the reverse bearings as a check.

To expedite the work, the bearing of the north portion of the turnpike could have been taken while the compass was set at "*A*," and that of the south end while the compass was at *E*.

If some prominent object can be observed from several corners,

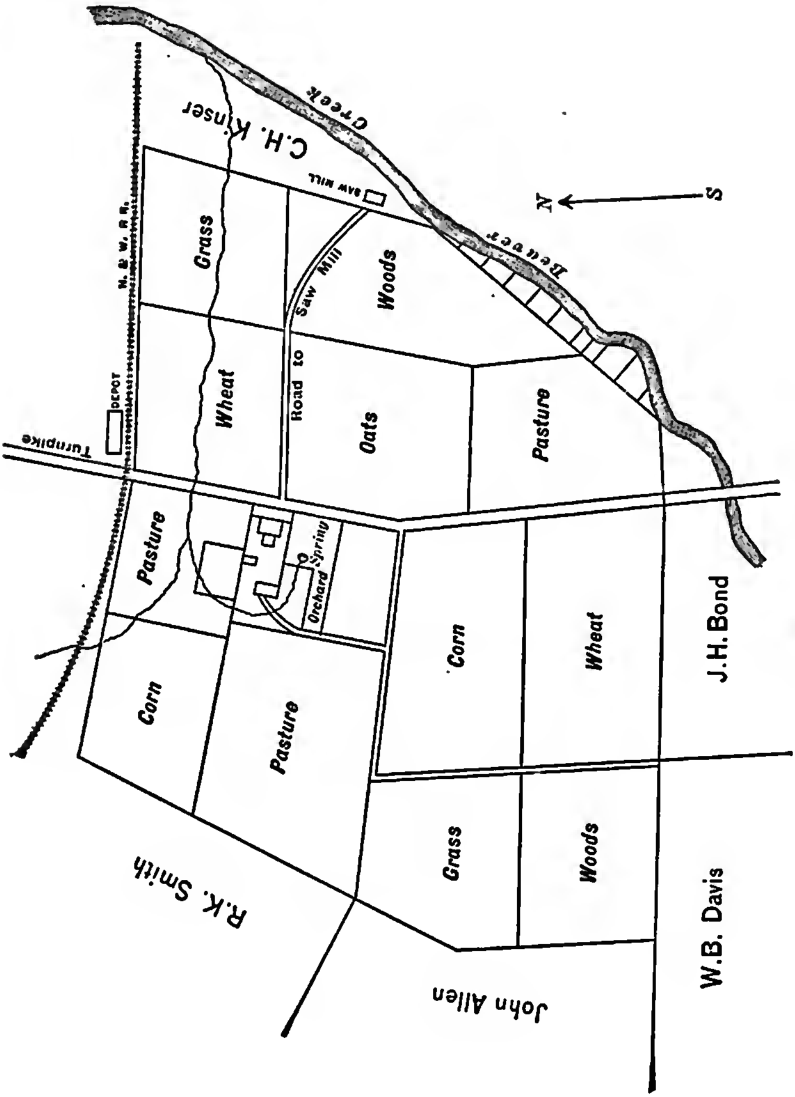


PLATE II.—Plot of a Farm

it is well to take sights on that object as a check on the work. For example, if there happened to be a tall tree, *T*, near the house, visible from *A*, *C*, and *E*, we should get the bearing of *AT*, *CT*, and *ET*. The check is furnished by the fact that on the plot the line *ET* should pass through the intersection of *AT* and *CT*. Such lines are called *tie lines*. If the transit is the instrument used, these tie lines, even in large, complicated surveys, often intersect exactly, but where the compass is used such exact intersections cannot be expected.

128. Report of a Survey. — A complete description, with plot, of any survey of private or public property made by a county surveyor is required by law to be furnished to the clerk of the county court, registrar of deeds, or some other official who is authorized to record the same. The surveyor is required in most states to give as a part of the description of the property the amount of declination of the needle, and whether east or west (see Art. 135), and also to append the names of the chainmen.

The bearings and distances are known as the "metes and bounds" of a survey. A common form of a "Survey Bill" is as follows:

"Description of the property known as the Buckeye Farm, near ——, in —— county, surveyed on the 5th day of February, 1901, and bounded as follows:

"Beginning at a point, the northeast corner of John Young's land and on J. K. Biddle's line, and marked by a cross X cut in top of a stone, thence along said Biddle's line S. 44° 9′ E., 21.63 ch. to a stone similarly marked; thence S. 7° 20′ E., 16.80 ch. to a stake, about 5 ft. north of a small white oak; thence S. 29° 10′ W., 40.49 ch. to a point on solid rock, the corner of Geo. Fox's land and the old patent line; thence along the patent line S. 68° 49′ W., 9.31 ch. to a locust post, with a spike in its top; thence N. 5° 16′ E., 21.15 ch. to a walnut root on south bank of a small creek, a corner of John Young's land; thence, with John Young's line, N. 10° 32′ E., 50.71 ch. to the beginning, containing 106.9 A. more or less.

"Magnetic bearings given.
"Declination, 1° 10′ W.

JOHN MACKY, *Surveyor*.
GEORGE DALE, DAVID JONES, } *Chainmen*."

129. Surveying Party. — For the survey of a large farm, the surveying party should be composed of four persons, — the compass-man,

two chainmen, and a rodman to carry the range-pole. The latter should be provided with an axe. If there is much undergrowth, another axeman may be needed. In small surveys, a compass-man with one assistant can do the work, the compass-man and his assistant chaining the course after its bearing has been taken.

RE-SURVEYS

130. Besides running new lines in making the original survey of a farm, or in dividing an estate into certain parts, the surveyor is frequently called upon to re-survey a farm, which involves the re-running of old lines. This is as important as any work in connection with the survey of farms, and is generally the most difficult, requiring a great deal of patience and good judgment. The difficulty arises mainly from two causes: *first*, the unscientific, if not careless, way in which old surveyors did their work, including the omission of permanent monuments to mark the corners; *second*, the uncertain behavior of the magnetic needle.

The defects of the magnetic needle have been referred to, and will be further considered in a subsequent section of this chapter. It is certain, however, that inconsistencies due to the sins of the surveyor have often been attributed to "defects" in the needle.

Now, if the surveyor has been furnished with the original field notes (metes and bounds) of a farm that he is asked to re-survey, so as to reëstablish the old lines and corners, the cases that may arise will probably come under one of the following heads:

FIRST. — Given the field notes, the declination of the needle, and one corner (with or without the date of the survey).

SECOND. — Given the field notes, the date of the survey, and one corner.

THIRD. — Given the field notes, the direction of one course, and one corner.

FOURTH. — Given the field notes, and one corner.

In any case, if no corner is certain, the first step is to endeavor, by the use of the surveys of adjacent tracts or some other available data, to locate at least one corner. In making the re-survey, the surveyor would proceed as follows:

131. First Case. — The present declination of the needle must be obtained (Art. 140). The difference between this value and the declination as given in the original notes tells how much the needle has varied since the former survey was made. Now, if a vernier compass is used, set off the variation thus found in the proper direction, and starting at the given corner, run the lines in order, using the original bearings. If the instrument is not a *vernier* compass, change all the bearings by the required amount, and using the *changed* bearings begin at the given corner and run the lines in order. In either case the original lines ought to be exactly reproduced. Another corner is often discovered and identified in this way which furnishes a verification of the work. For example, suppose the following field notes were taken when the declination was 3° 50′ E.:

Stations	Bearings	Distances
A	N. 52° E.	10.64
B	S. 29¾° E.	4.09
C	S. 31¾° W.	7.68
D	N. 61° W.	7.24

Corner "*B*" known, present declination = 2° 45′ E.

Here the needle has changed 1° 5′ (3° 50′ − 2° 45′); that is, the north end of the needle has, in the interval between the surveys, swung west 1° 5′. Hence, with the vernier change the N. and S. line of the compass-box 1° 5′ in the proper direction. (Clockwise or counter-clockwise?) Or else (if vernier compass is not used) change the bearings, making them read N. 53° 5′ E., S. 28° 40′ E., S. 32° 50′ W., N. 59° 55′ W., and, using these new bearings, run out the lines in order, beginning at *B*.

132. Second Case. — Given the date of survey, 1880, and the field notes.

We must in this case ascertain, as near as possible, the declination in 1880. If other surveys made in the same locality during the year 1880 record the declination, that value may be assumed, and the difference between that and the present declination is used exactly as we have done in the first case. If no such record exists, then get from published tables, or other available sources, the annual variation of the needle. This multiplied by the time that has elapsed since 1880 will give an approximate value for the change

in the declination. If the annual change is taken as 3 min., and the re-survey is made in 1902, then

$$3 \times (1902 - 1880) = 66 \text{ min.} = 1° \ 6',$$

is the variation to be used.*

133. THIRD CASE. — Given, besides the field notes, the direction of one course and one corner.

The known corner may or may not be adjacent to the course whose direction is given. The direction of a line may be well established by the foundation of an old stone fence, for example, or by certain "marked" trees, or by the fact that a portion of it coincides with a known line of some other farm. When this is the case, set up the compass at some point on the known line and sight a pole held at another point on the line. Note the difference between the reading of the needle and the bearing as given in the notes; this difference represents the change in the declination, and as we have seen, is all that it is necessary to know in order to re-run the old lines.

134. The *fourth case*, where we have a corner given and nothing else except the field notes, does not admit of a ready or certain solution. Unless the surveyor can, by running trial lines, discover some old marks, or find in the description of adjoining tracts of land some data concerning either the date of the field notes or the probable declination of the needle at the time of the survey, the problem cannot be solved. In such a case it becomes the duty of the surveyor to use due diligence in hunting up old records, and examining the ground embracing the tract in question for any possible marks. He should by no means despise testimony furnished by old residents, which, though seemingly trivial, may give a valuable clew.

It is beyond the scope of this book to consider the principles and laws concerning the re-survey of private lands. The reader is referred to "Johnson's Surveying," already mentioned, for an excellent brief presentation of this matter; here he will find given the substance of many state supreme court decisions on disputed points.†

* CAUTION. — If the field notes are found in a deed dated 1880, it does not necessarily follow that the survey was made at that time; for the field notes, as often happens, may have been copied from a former deed. The author has found this to be the case more than once.

† A large list of rules based on supreme court decisions will be found in Hodgman's "Manual of Land Surveying."

The foregoing shows plainly how important it is for the surveyor to mark all corners with durable monuments, such as a large stone buried in the ground below the frost line, with the position of *the corner* indicated by a cross or some other mark.

II. THE DECLINATION OF THE NEEDLE

135. The magnetism of the earth, while a very powerful force, is still in great measure a mystery; but we do know that the earth apparently acts as a great magnet, the poles of which do not coincide with the geographic poles, but are situated some distance from them. The magnetic meridian does not in most places coincide with the true (or astronomical) meridian, but makes an angle with it. This angle is called the *declination of the needle.* Moreover, this angle is not the same for any two places on different magnetic meridians, and is not constant for any one place. For example, in the northern states the change in declination in an east and west direction will average about *one minute to the mile,* so that the value of the declination in the east end of a county may be some *forty minutes* in error in the west end of the same county, while in any one place its value may be changing at the rate of from *two* to *six minutes* a year (sometimes less than 2′, occasionally more than 6′, see Table VII, page 78). This *change* in the declination is called the *variation* * of the needle.

136. There is one imaginary line in the Western Hemisphere,† passing through the magnetic poles, at every point of which the needle points truly north. It is called the *Line of No Declination,* or *Agonic Line,* because for all points on this line the declination is zero. At all points east of the line the declination is *west,* and at all points west of it the declination is *east,* for east of the agonic line the needle points *west* of true north, and west of it the needle points *east* of true north. In America the line of no declination has been moving westward since about the year 1800. An examination of the Declination Map ‡ (Plate I) at the beginning of this volume shows that in 1910 the agonic line passed just east of Savannah, Ga., through the western part of South Carolina and North Carolina, nearly through Columbia, S.C., a little east of Asheville, N.C.,

* The terms are found used in rather a confusing way, "variation" often being used for "declination."

† There is a similiar one in the Eastern Hemisphere.

‡ Reduced from a map published in 1911 by the United States Coast and Geodetic Survey.

through the eastern part of Tennessee and Kentucky, just missing the extreme western corner of Virginia, thence through Ohio, the northeast corner of Indiana, and Michigan, passing near Grand Rapids in the latter state.

137. Historic Note. — It seems that Chinese vessels were guided by the magnetic needle certainly as early as the third and fourth centuries of our era. Its use seems to have spread from China to western (European) nations rather slowly, as the first notice of the magnetic needle as applied to navigation dated back no farther than the eleventh or twelfth century. In China the directive property of the needle was made use of on land as early as the twelfth century B.C. The declination of the needle must have been observed some centuries before Columbus crossed the Atlantic, but prior to that time the fact that the needle did not point truly north was supposed to be due to some imperfection of the needle in use, and even as late as the sixteenth century the same view was commonly held. But to Columbus belongs the credit of discovering not only the line of no declination, but the declination itself.*

He crossed the agonic line in September, 1492, a little west of Fayal Island, of the Azores. The needle, which had been pointing *east* of north, was observed to point *west* of north, a fact which caused much alarm on board ship. The discovery of the gradual change in the declination, which for any one place had previously been supposed to be constant, was made by Gellibrand of England in 1635.

138. We notice three kinds of variation.

First, *Irregular Variation.* — Under this head may be classed changes due to magnetic storms which occur at no regular intervals and are of varying degrees of intensity and extent. In duration these magnetic storms (which must not be confounded with electric storms) may be confined to a few hours, or they may last a day, or even for several days. Erratic changes of the needle, made manifest when the compass is moved, are often due to mineral deposits or even more local causes.

Second, *Daily Variation.* — The daily variation in the declination, which amounts to about 8 min., is caused by the swinging of the needle through an arc daily, the north end reaching its extreme easterly position about 8 A.M., and its extreme westerly position about 1.30 P.M. It has its mean or true declination about 10.30 A.M. and 8 P.M. This variation is a little greater in summer than in winter, as an examination of the following table † will show.

* See Maryland Geological Survey, "First Report on Magnetic Work in Maryland," by Dr. L. A. Bauer.

† Values given to nearest minute. Condensed from a table giving the results of observations made at the Washington Magnetic Observatory.

TABLE V

DAILY VARIATION OF THE NEEDLE

MONTH	6 A.M.	7	8	9	10	11	NOON	1	2	3	4	5	6 P.M.
January	0	0	+1′	+2′	+2′	+1′	−1′	−2′	−3′	−2′	−1′	0	0
April	+2	+3	+3	+3	+1	−2	−4	−4	−4	−4	−2	−1	0
July	+3	+5	+5	+4	+2	−1	−3	−4	−5	−4	−3	−1	0
October	+1	+2	+3	+3	+1	−1	−3	−3	−3	−2	−1	0	0

This shows that a difference of at least 8 or 10 min. in the direction of a line may be made if no account is taken of the daily variation. Surveyors in this country usually neglect this variation.

139. THIRD, *Secular Variation.* — The most important change in the direction of the needle is the secular variation, so called because it has a period of several centuries. We do not know, however, that the change is strictly periodic, for we do not possess at any one station records of a complete swing of the needle. It is not the same at different places, as the records that we have, embracing more than a "half-swing" at some stations, clearly show. From these records we find, for example, at London, Paris, and Rome the time interval between dates of extreme positions (half-swings) of the needle is about 230 to 240 years, while for stations in the eastern states of this country it averages about 150 years. At Paris the maximum easterly declination of 9° 36′ was reached in the year 1580, and the maximum westerly declination of 22° 36′ in about 1809, a difference of 32° 12′ in 229 years. At Baltimore the needle pointed about 6° 6′ west in 1670, and in 1802 it pointed the least amount west, 0° 39′; hence, in an interval of 132 years, the change was 5° 27′. These records of Paris and Baltimore illustrate the fact that not only is the period different at different places, but the amounts of change are not proportional to the lengths of the periods. Paris and Baltimore are no exceptions to the general rule, and this is convincing proof of the importance of investigating with great care the declination at any place at the time of a survey with a needle-compass.

On pages 76, 77, and 78 appear Tables VI and VII, condensed from similar tables to be found in *Special Publication No.* 9, on Terrestrial Magnetism, of the United States Coast and Geodetic Survey (1911). These tables, in connection with the isogonic

TABLE VI

Secular Change of the Magnetic Declination in the United States

Place	Lat.	Long.	Decl'n 1780	Decl'n 1800	Decl'n 1820
	° ′	° ′	° ′	° ′	° ′
Montgomery, Ala.	32 22	86 18	4 34 E.	5 24 E.	5 47 E.
Holbrook, Ariz.	34 55	110 10			
Little Rock, Ark.	34 47	92 18		8 15 E.	8 51 E.
San José, Cal.	37 18	121 52	13 37 E.	14 32 E.	15 30 E.
Pueblo, Colo.	38 14	104 38			
Hartford, Conn.	41 45	72 40	4 45 W.	4 51 W.	5 34 W.
Dover, Del.	39 09	75 31	1 52 W.	1 33 W.	1 52 W.
Washington, D.C.	38 55	77 02	0 01 W.	0 28 E.	0 19 E.
Tampa, Fla.	27 58	82 28	6 15 E.	6 30 E.	6 15 E.
Macon, Ga.	32 51	83 37	5 01 E.	5 44 E.	5 53 E.
Boise, Idaho	43 37	116 12			
Bloomington, Ill.	40 31	88 59		5 54 E.	6 33 E.
Indianapolis, Ind.	39 47	86 12		4 44 E.	5 04 E.
Des Moines, Iowa	41 36	93 36			10 09 E.
Emporia, Kan.	38 25	96 12			
Lexington, Ky.	38 04	84 30		4 22 E.	4 31 E.
Alexandria, La.	31 21	92 25		8 04 E.	8 41 E.
Portland, Me.	43 39	70 17	8 20 W.	8 44 W.	9 48 W.
Baltimore, Md.	39 18	76 35	1 25 W.	0 56 W.	1 05 W.
Boston, Mass.	42 20	71 01	6 50 W.	7 01 W.	7 47 W.
Lansing, Mich.	42 44	84 32			4 10 E.
Mankato, Minn.	44 11	93 59			11 20 E.
Jackson, Miss.	32 20	90 11		7 54 E.	8 24 E.
Sedalia, Mo.	38 43	93 14			10 03 E.
Helena, Mont.	46 37	112 02			
Hastings, Neb.	40 37	98 24			11 39 E.
Elko, Nev.	40 51	115 46			
Hanover, N.H.	43 43	72 17	6 47 W.	6 49 W.	7 32 W.
Trenton, N.J.	40 14	74 48	3 06 W.	2 45 W.	3 06 W.
Santa Rosa, N.M.	34 56	104 41			
Albany, N.Y.	42 40	73 45	5 50 W.	5 28 W.	5 50 W.
Newbern, N.C.	35 07	77 03	1 17 E.	1 44 E.	1 35 E.
Jamestown, N.D.	46 54	98 43			
Columbus, Ohio	39 59	83 01		3 13 E.	3 22 E.
Enid, Okla.	36 24	97 55			
Sumpter, Ore.	44 45	118 13			
Philadelphia, Pa.	39 57	75 12	2 44 W.	2 08 W.	2 22 W.
Newport, R.I.	41 30	71 20	6 03 W.	6 19 W.	7 05 W.
Columbia, S.C.	34 00	81 02	3 44 E.	4 19 E.	4 19 E.
Huron, S.D.	44 21	98 14			
Chattanooga, Tenn.	35 01	85 18		5 07 E.	5 16 E.
San Antonio, Texas	29 29	98 32			
Salt Lake, Utah	40 46	111 54			
Rutland, Vt.	43 37	72 58	6 28 W.	6 30 W.	7 13 W.
Richmond, Va.	37 33	77 28	0 20 E.	0 47 E.	0 38 E.
Seattle, Wash.	47 40	122 18	17 19 E.	18 27 E.	19 04 E.
Charleston, W.Va.	38 21	81 38		2 15 E.	2 15 E.
Madison, Wis.	43 04	89 25			8 34 E.
Douglas, Wyo.	42 44	105 22			

TABLE VI — *Continued*

SECULAR CHANGE OF THE MAGNETIC DECLINATION IN THE UNITED STATES

DECL'N 1840	DECL'N 1850	DECL'N 1860	DECL'N 1870	DECL'N 1880	DECL'N 1890	DECL'N 1900
° '	° '	° '	° '	° '	° '	° '
5 38 E.	5 22 E.	5 00 E.	4 32 E.	3 54 E.	3 15 E.	2 49 E.
	13 33 E.	13 44 E.	13 47 E.	13 40 E.	13 25 E.	13 30 E.
8 59 E.	8 51 E.	8 34 E.	8 14 E.	7 38 E.	7 01 E.	6 38 E.
16 22 E.	16 45 E.	17 05 E.	17 20 E.	17 24 E.	17 28 E.	17 50 E.
	13 47 E.	13 50 E.	13 46 E.	13 31 E.	13 00 E.	12 53 E.
6 47 W.	7 31 W.	8 09 W.	8 43 W.	9 24 W.	9 49 W.	10 23 W.
2 46 W.	3 23 W.	4 03 W.	4 41 W.	5 20 W.	5 51 W.	6 29 W.
0 28 W.	1 02 W.	1 41 W.	2 21 W.	3 00 W.	3 36 W.	4 11 W.
5 30 E.	5 00 E.	4 28 E.	3 53 E.	3 16 E.	2 48 E.	2 19 E.
5 26 E.	5 01 E.	4 29 E.	3 53 E.	3 14 E.	2 39 E.	2 08 E.
	18 00 E.	18 30 E.	18 45 E.	18 45 E.	18 39 E.	18 51 E.
6 33 E.	6 18 E.	5 54 E.	5 26 E.	4 51 E.	4 10 E.	3 35 E.
4 44 E.	4 21 E.	3 50 E.	3 20 E.	2 45 E.	2 05 E.	1 28 E.
10 30 E.	10 24 E.	10 09 E.	9 44 E.	9 06 E.	8 21 E.	7 52 E.
	11 34 E.	11 28 E.	11 15 E.	10 50 E.	10 14 E.	9 56 E.
4 04 E.	3 39 E.	3 07 E.	2 33 E.	1 57 E.	1 17 E.	0 42 E.
8 48 E.	8 40 E.	8 24 E.	8 00 E.	7 26 E.	6 55 E.	6 35 E.
11 07 W.	11 48 W.	12 28 W.	12 58 W.	13 32 W.	14 00 W.	14 26 W.
1 52 W.	2 26 W.	3 05 W.	3 45 W.	4 24 W.	5 00 W.	5 35 W.
9 04 W.	9 48 W.	10 28 W.	11 01 W.	11 30 W.	11 58 W.	12 33 W.
3 46 E.	3 20 E.	2 46 E.	2 04 E.	1 17 E.	0 32 E.	0 01 W.
11 42 E.	11 36 E.	11 20 E.	10 54 E.	10 22 E.	9 32 E.	8 57 E.
8 24 E.	8 13 E.	7 57 E.	7 31 E.	6 58 E.	6 25 E.	6 01 E.
10 13 E.	10 04 E.	9 46 E.	9 25 E.	8 46 E.	8 05 E.	7 39 E.
18 53 E.	19 18 E.	19 36 E.	19 45 E.	19 34 E.	19 23 E.	19 31 E.
12 07 E.	12 07 E.	11 59 E.	11 42 E.	11 12 E.	10 35 E.	10 14 E.
	17 20 E.	17 36 E.	17 41 E.	17 44 E.	17 38 E.	17 49 E.
8 56 W.	9 46 W.	10 31 W.	11 08 W.	11 38 W.	12 01 W.	12 36 W.
4 04 W.	4 43 W.	5 22 W.	6 01 W.	6 41 W.	7 11 W.	7 46 W.
	12 43 E.	12 47 E.	12 43 E.	12 25 E.	12 00 E.	11 54 E.
6 53 W.	7 39 W.	8 25 W.	9 04 W.	9 51 W.	10 12 W.	10 50 W.
0 50 E.	0 17 E.	0 19 W.	1 00 W.	1 40 W.	2 16 W.	2 52 W.
	14 10 E.	14 00 E.	13 42 E.	13 13 E.	12 30 E.	12 07 E.
2 53 E.	2 24 E.	1 50 E.	1 14 E.	0 37 E.	0 02 W.	0 42 W.
	11 13 E.	11 08 E.	10 56 E.	10 33 E.	10 06 E.	9 46 E.
	19 15 E.	19 40 E.	19 58 E.	20 09 E.	20 11 E.	20 26 E.
3 21 W.	4 04 W.	4 46 W.	5 25 W.	6 03 W.	6 43 W.	7 23 W.
8 22 W.	9 06 W.	9 46 W.	10 19 W.	10 50 W.	11 17 W.	11 52 W.
3 44 E.	3 15 W.	2 41 W.	2 03 W.	1 25 W.	0 47 W.	0 12 E.
13 06 E.	13 06 E.	12 57 E.	12 40 E.	12 15 E.	11 35 E.	11 08 E.
4 49 E.	4 24 E.	3 52 E.	3 16 E.	2 36 E.	2 01 E.	1 30 E.
9 48 E.	9 53 E.	9 48 E.	9 37 E.	9 19 E.	8 52 E.	8 43 E.
	16 25 E.	16 38 E.	16 43 E.	16 38 E.	16 23 E.	16 28 E.
8 29 W.	9 13 W.	9 50 W.	10 30 W.	11 19 W.	11 42 W.	12 17 W.
0 05 W.	0 36 W.	1 12 W.	1 51 W.	2 29 W.	3 06 W.	3 40 W.
20 49 E.	21 19 E.	21 45 E.	22 06 E.	22 19 E.	22 32 E.	22 54 E.
1 37 E.	1 05 E.	0 30 E.	0 12 W.	0 51 W.	1 28 W.	2 06 W.
8 34 E.	8 16 E.	7 49 E.	7 14 E.	6 25 E.	5 40 E.	5 05 E.
	15 51 E.	15 59 E.	15 59 E.	15 49 E.	15 19 E.	15 15 E.

TABLE VII

Secular Change of the Magnetic Declination — *Continued*

Place	Decl'n 1905	Decl'n 1910	Annual Change in 1910
	° ′	° ′	
Montgomery, Ala.	2 48 E.	2 45 E.	− 0.7
Holbrook, Ariz.	13 42 E.	14 05 E.	+ 4.3
Little Rock, Ark.	6 42 E.	6 49 E.	+ 1.4
San José. Cal.	18 10 E.	18 32 E.	+ 4.5
Pueblo, Colo.	13 04 E.	13 19 E.	+ 3.1
Hartford, Conn.	10 43 W.	11 11 W.	+ 5.8
Dover, Del.	6 48 W.	7 13 W.	+ 4.8
Washington, D.C.	4 29 W.	4 51 W.	+ 4.5
Tampa, Fla.	2 11 E.	2 06 E.	− 0.8
Macon, Ga.	2 02 E.	1 52 E.	− 2.0
Boise, Idaho	19 08 E.	19 31 E.	+ 4.5
Bloomington, Ill.	3 29 E.	3 25 E.	− 0.8
Indianapolis, Ind.	1 18 E.	1 08 E.	− 1.8
Des Moines, Iowa	7 53 E.	7 57 E.	+ 1.0
Emporia, Kan.	9 59 E.	10 08 E.	+ 1.8
Lexington, Ky.	0 30 E.	0 19 E.	− 2.0
Alexandria, La.	6 40 E.	6 50 E.	+ 1.8
Portland, Me.	14 43 W.	15 13 W.	+ 6.0
Baltimore, Md.	5 53 W.	6 15 W.	+ 4.5
Boston, Mass.	12 52 W.	13 21 W.	+ 6.0
Lansing, Mich.	0 15 W.	0 27 W.	+ 2.4
Mankato, Minn.	8 54 E.	9 00 E.	+ 1.2
Jackson, Miss.	6 03 E.	6 08 E.	+ 1.0
Sedalia, Mo.	7 41 E.	7 46 E.	+ 1.2
Helena, Mont.	19 45 E.	20 02 E.	+ 3.7
Hastings, Neb.	10 19 E.	10 28 E.	+ 2.0
Elko, Nev.	18 04 E.	18 27 E.	+ 4.6
Hanover, N.H.	12 46 W.	13 16 W.	+ 6.0
Trenton, N.J.	8 07 W.	8 33 W.	+ 5.2
Santa Rosa, N.M.	12 10 E.	12 29 E.	+ 3.6
Albany, N.Y.	11 05 W.	11 31 W.	+ 5.6
Newbern, N.C.	3 08 W.	3 25 W.	+ 3.4
Jamestown, N.D.	12 15 E.	12 24 E.	+ 1.8
Columbus, Ohio	0 55 W.	1 10 W.	+ 2.8
Enid, Okla.	9 52 E.	10 06 E.	+ 2.6
Sumpter, Ore.	20 44 E.	21 07 E.	+ 4.6
Philadelphia, Pa.	7 42 W.	8 07 W.	+ 5.0
Newport, R.I.	12 11 W.	12 40 W.	+ 6.0
Columbia, S.C.	0 00	0 12 W.	+ 2.6
Huron, S.D.	11 18 E.	11 28 E.	+ 1.8
Chattanooga, Tenn.	1 22 E.	1 12 E.	− 2.0
San Antonio, Texas	8 53 E.	9 09 E.	+ 3.0
Salt Lake, Utah	16 42 E.	17 03 E.	+ 4.2
Rutland, Vt.	12 27 W.	12 57 W.	+ 6.0
Richmond, Va.	3 55 W	4 13 W.	+ 4.0
Seattle, Wash.	23 14 E.	23 40 E.	+ 5.0
Charleston, W.Va.	2 23 W.	2 39 W.	+ 3.4
Madison, Wis.	4 56 E.	4 51 E.	− 1.0
Douglas, Wyo.	15 27 E.	15 43 E.	+ 3.2

chart* given at the beginning of this book may assist the surveyor in forming some idea of what the declination is at his station, in the event of his having no true meridian line to test his compass by. An examination of the tables should cause him to be cautious in adopting a value for the annual change in the declination, and at the same time he should remember that there are often local peculiarities not brought out in the formulæ.

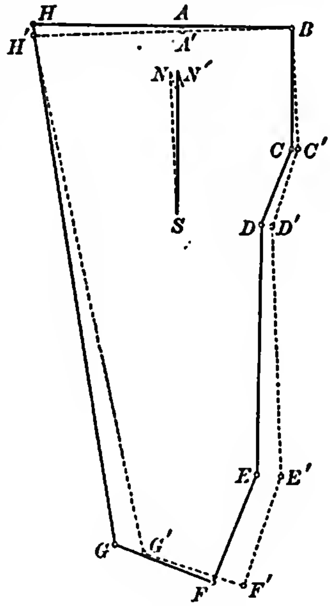


Fig. 48

The following example from actual practice (Fig. 48) is given as an illustration of the change in the position of a farm, if no account is taken of the variation of the declination. As a re-survey, it comes under our 2d case, Art. 132.

A deed containing the metes and bounds, dated 1880, was furnished the surveyor in 1902, with the request that he re-survey the farm. Before commencing work, he looked up a deed given to the farmer who owned the land prior to 1880. This deed, which was dated 1849, contained the identical field notes, showing that no re-survey was made in 1880. Going no farther back than this, he assumed that the notes were taken in 1849.

He had reason to suppose that the declination in 1849 was 6° E. The declination in 1902 was 2° 45′ E. Assuming these values to be correct, the variation in the 53 years amounted to 3° 15′; that is, in that interval of time the north end of the needle had swung west 3° 15′.

Accordingly he changed all the bearings by that amount and ran out the lines, *BC*,† *CD*, etc., represented by the full lines in Fig. 48. These were doubtless very near to the actual lines run out in 1849. Had he used the old bearings, he would have run out the erroneous boundary represented by the dotted lines. Notice that the dotted arrow, *SN*, is the direction of the needle in 1902, and *SN′* its direc-

* Isogonic lines are lines of equal declination. This chart, for which the author is indebted to the United States Coast and Geodetic Survey, is a decided improvement over all previous declination maps. It will be observed that an isogonic line is far from being a smooth curve. In fact, the more accurate and numerous the observations are, the greater the sinuosities of the isogonic lines.

† The corner *B* was the only corner known.

tion in 1849. The original field notes were as follows: Beginning at *A*, east, 40 poles; *B*, south, 44 poles; *C*, S. 20° W., 29 poles; *D*, south, 90 poles; *E*, S. 20° W., 42 poles; *F*, N. 70° W., 38 poles; *G*, N. 10° W., 190 poles; *H*, east, 56 poles. After being changed, the bearing of *AB* was S. 86° 45′ E., that of *BC*, S. 3° 15′ W., etc.

140. To determine the Declination. — The declination of a magnetic needle at any place is obtained by comparing the direction of that needle with a *true* (or *geographical*) *meridian line*. Hence, there should be established in every town or county a true meridian line, and every surveyor should be required by law to test his compass by this line at least once a year, at the same time of day.* This is a law in most, if not all, of the states; but, unfortunately, in many instances it is a dead letter. We shall now consider some simple methods of establishing a true meridian line.

III. THE DETERMINATION OF A TRUE MERIDIAN LINE†

141. To obtain the direction of the true meridian at any place it would suffice to get the direction of Polaris, or some other circumpolar star (Art. 23), exactly at its upper or lower culmination (Art. 24); but, as the star is at such times moving very rapidly in azimuth, this calculation would require an accurate knowledge of the local time. For this reason it is customary to take observations when the star is at either eastern or western elongation, and then to lay off to the west or east, as the case may be, an angle equal to the azimuth of the star (Art. 20). This is done in the first two methods given below.

Polaris, owing to its proximity to the north pole and its being so readily distinguished, is the most suitable star for this purpose. Its extreme east and west positions are called its *eastern* and *western elongations* respectively. When it is at elongation, it ceases to have any perceptible lateral motion, and moves vertically upward at eastern, and downward at western elongation. If the star be observed at elongation, the observer's watch may be as much as

* This remedy for the evils arising from ignorance of the value of the declination is said to have been first suggested by David Rittenhouse.

† The general descriptions of the three methods here given are taken almost *verbatim* from the United States Land Office Manual of Surveying Instructions, Washington, 1894. The author has made a few changes and some additional explanations.

15 minutes in error without causing any appreciable error in the result.

Table VIII gives the azimuths of Polaris at elongation for any year between 1914 and 1924, and for any latitude between + 25° and + 50°.

TABLE VIII

AZIMUTHS OF POLARIS WHEN AT ELONGATION FOR ANY YEAR BETWEEN 1914 AND 1924, AND FOR ANY LATITUDE BETWEEN + 25° AND + 50°

Lat.	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
25	1 16.4	16.0	15.7	15.3	15.0	14.7	14.3	14.0	13.6	13.3
26	17.0	16.6	16.3	16.0	15.6	15.3	14.9	14.7	14.2	13.9
27	17.7	17.3	17.0	16.6	16.3	15.9	15.6	15.2	14.9	14.6
28	18.4	18.0	17.7	17.3	17.0	16.6	16.3	15.9	15.6	15.2
29	19.1	18.8	18.4	18.1	17.7	17.4	17.0	16.6	16.3	16.0
30	19.9	19.6	19.2	18.8	18.5	18.1	17.8	17.4	17.0	16.7
31	20.7	20.4	20.0	19.7	19.3	18.9	18.6	18.2	17.9	17.5
32	21.6	21.2	20.9	20.5	20.1	19.8	19.4	19.1	18.7	18.3
33	22.5	22.1	21.8	21.4	21.0	20.7	20.3	19.9	19.6	19.2
34	23.5	23.1	22.7	22.4	22.0	21.6	21.2	20.9	20.5	20.1
35	24.5	24.1	23.7	23.3	23.0	22.6	22.2	21.8	21.5	21.1
36	25.5	25.2	24.8	24.4	24.0	23.6	23.3	22.9	22.5	22.1
37	26.7	26.3	25.9	25.3	25.1	24.7	24.3	24.0	23.6	23.2
38	27.8	27.4	27.0	26.6	26.2	25.9	25.5	25.1	24.7	24.3
39	29.0	28.6	28.2	27.8	27.5	27.1	26.7	26.3	25.8	25.5
40	30.3	29.9	29.5	29.1	28.7	28.3	27.9	27.5	27.1	26.7
41	31.7	31.3	30.9	30.4	30.0	29.6	29.1	28.8	28.4	28.0
42	33.1	32.7	32.3	31.9	31.5	31.0	30.6	30.2	29.8	29.4
43	34.6	34.2	33.8	33.4	32.9	32.5	32.1	31.8	31.2	30.8
44	36.2	35.8	35.3	34.9	34.5	34.1	33.6	33.2	32.8	32.4
45	37.8	37.4	37.0	36.6	36.1	35.7	35.3	34.8	34.4	34.0
46	39.6	39.2	38.7	38.3	37.8	37.4	37.0	36.5	36.1	35.6
47	41.5	41.0	40.6	40.1	39.7	39.2	38.8	38.3	37.9	37.4
48	43.4	43.0	42.5	42.0	41.6	41.1	40.7	40.2	39.8	39.3
49	45.5	45.0	44.5	44.1	43.6	43.1	42.7	42.2	41.7	41.3
50	1 47.7	1 47.2	1 46.7	1 46.2	1 45.7	1 45.3	1 44.8	1 44.3	1 43.8	1 43.4

In Table IX are given the times of the culminations and elongations of Polaris for the year 1915. The surveyor selects an elongation or culmination that does not occur in the daytime.

TABLE IX

LOCAL MEAN (ASTRONOMICAL*) TIME OF THE CULMINATIONS AND ELONGATIONS OF POLARIS IN THE YEAR 1903.

[Computed † for latitude +40° and longitude 6 hr. west of Greenwich.]

DATE	EAST ELONGATION	UPPER CULMINATION	WEST ELONGATION	LOWER CULMINATION
1915	h m	h m	h m	h m
January 1	0 51.7	6 46.9	12 42.1	18 44.9
January 15	23 52.5	5 51.6	11 46.8	17 49.6
February 1	22 45.3	4 44.5	10 39.7	16 42.5
February 15	21 50.1	3 49.2	9 44.4	15 47.2
March 1	20 54.8	2 54.0	8 49.2	14 52.0
March 15	19 59.6	1 58.8	7 54.0	13 56.8
April 1	18 52.7	0 51.9	6 47.1	12 49.9
April 15	17 57.7	23 52.9	5 52.0	11 54.8
May 1	16 54.8	22 50.0	4 49.2	10 52.0
May 15	15 59.9	21 55.1	3 54.2	9 57.0
June 1	14 53.3	20 48.5	2 47.6	8 50.4
June 15	13 58.5	19 53.7	1 52.8	7 55.6
July 1	12 55.9	18 51.1	0 50.2	6 53.0
July 15	12 01.1	17 56.3	23 51.5	5 58.2
August 1	10 54.5	16 49.7	22 44.9	4 51.7
August 15	9 59.8	15 55.0	21 50.2	3 56.9
September 1	8 53.2	14 48.4	20 43.6	2 50.3
September 15	7 58.3	13 53.5	19 48.7	1 55.4
October 1	6 55.5	12 50.7	18 45.9	0 52.7
October 15	6 00.6	11 55.8	17 51.0	23 53.8
November 1	4 53.7	10 48.9	16 44.1	22 46.9
November 15	3 58.6	9 53.8	15 49.0	21 51.8
December 1	2 55.6	8 50.8	14 46.0	20 48.8
December 15	2 00.4	7 55.6	13 50.8	19 53.6

It will be noticed that for the tabular year two eastern elongations occur on Jan. 14, two western elongations on July 13, two upper culminations on April 14, and two lower culminations on Oct. 14. The lower culmination either follows or precedes the upper culmination by 11 hr. 58.1 min.

142. Reduction to Other Dates. — (*a*) For the years up to 1924 add the following minutes to the quantities given in Table IX:

* The *astronomical* day begins 12 hr. *after* the civil day; *i.e.* commences at noon on the civil day of the same date. The hours are counted from noon, from 0 to 24.

† This table was obtained from one given in "Principal Facts of the Earth's Magnetism," published by the United States Coast and Geodetic Survey in 1909.

1914	1916	1917	1918	1919	1920	1921	1922	1923
− 1.5	+ 1.6 − 2.3	− 0.7	+ 0.9	+ 2.5	+ 4.0 + 0.1	+ 1.6	+ 3.1	+ 4.5

(*b*) To refer to any calendar day other than the 1st and 15th of each month, subtract 3.92 min. for every day between it and the preceding tabular day, or add 3.92 min. for every day between it and the succeeding tabular day.

(*c*) The correction for longitude is so small that it may usually be neglected. It amounts to 0.16 min. subtractive for each hour west of 6 hr.

(*d*) To refer to any other than the tabular latitude between the limits of 25° and 50° north, add to the time of west elongation 0.10 min. for every degree *south* of 40°, and subtract from the time of west elongation 0.16 min. for every degree *north* of 40°; reverse these signs for corrections to times of east elongation.

(*e*) *To refer the Table to Standard Time.*—The time given in Table IX is the *local* time at the place of observation. As *hourly meridian* (or standard) time is now carried at most places in this country to the complete exclusion of local time, it will be necessary to reduce the tabular local time to standard time. To do this we must know the longitude of the place, which can usually be determined with sufficient accuracy from a map. If l denotes this longitude reckoned from Greenwich, we apply to the tabular quantities a correction (in minutes) equal to $4(l - L)$, where $L = 75°$, $90°$, $105°$, or $120°$, according as the place is in the Eastern, Central, Mountain, or Western time belts; that is, we add a correction of *four* minutes to every degree west of the time meridian. The correction is *negative* if the place is east of its time meridian.

NOTE.—The *Civil Day*, according to the customs of society, commences at midnight and comprises 24 hr., from one midnight to the next following. The hours are counted from 0 to 12, from midnight to noon, after which they are again reckoned from 0 to 12, from noon to midnight. Thus the day is divided into two periods of 12 hr. each, the first of which is marked A.M., the last P.M.

The *Astronomical Day* commences at noon on the civil day of the same date. It also comprises 24 hr.; but they are reckoned from 0 to 24, from the noon of one day to that of the next following.

The civil day begins 12 hr. before the astronomical day; therefore the first period of the civil day answers to the last part of the preceding astronomical day.

* The upper number *before* March 1, the lower one *after* March 1.

Thus, Jan. 9, 2 hr. astronomical time, is also Jan. 9, 2 o'clock P.M., civil time; and Jan. 9, 14 hr., astronomical time, is Jan. 10, 2 o'clock A.M., civil time.

Example.—Suppose the time of the east elongation of Polaris is wanted for Oct. 3, 1903, at Sewance, Tenn. Sewance is in the Central time belt. Its position, as roughly obtained from a map, is assumed to be as follows: latitude, 35° 13′ N.; longitude, 85° 55′ W. From Table IX we find the time of east elongation for Oct. 1 to be 6 hr. 50.7 min.

Now, using (*c*), correction for long. = + 0.05 min.,
using (*d*), correction for lat. = − 0.62 min.

Hence, we have for

	h.	*m.*	
Oct. 1, 1903,	6	50.7	tabular time
Correction for lat. and long.		− 0.57	
	6	50.13	Sewanee local time
Time correction (see (*e*))		− 16.33	$4(l - 90°)$
Oct. 1, 1903	6	33.80	standard time
Daily change (see (*b*)),		− 3.94	
Oct. 2, 1903	6	29.86	
Oct. 3, 1903	6	25.92	

The following methods for determining the position of the north pole are easily carried out with the ordinary outfit of a surveyor.

143. To determine the True Meridian by Observation on Polaris at Elongation with the Engineer's or Surveyor's Transit.

1. Set a stone, or drive a wooden plug firmly into the ground, and upon the top thereof make a small distinct mark.

2. About 30 min. before the time of the eastern or western elongation of Polaris, as given by the tables of elongation (Table IX), set up the transit firmly, with its vertical axis exactly over the mark, and carefully level the instrument.

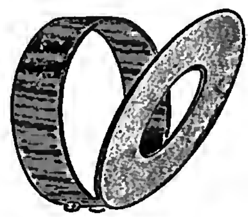
3. Illuminate the cross-wires by the light from a bull's-eye lantern or other source, the rays being directed into the object end of the telescope by an assistant. Great care must be taken to see that the line of collimation describes a truly vertical plane.

4. Place the vertical wire upon the star, which, if it has not reached its elongation, will move to the right for eastern and to the left for western elongation.

5. While the star moves toward its point of elongation, by means of the tangent screw of the vernier plate it will be continually covered by the vertical wire until a point is reached where it will appear to remain on the wire for some time, then leave it in a direction contrary to its former motion; this indicates the point of elongation.

6. At the instant the star appears to thread the vertical wire depress the telescope to a horizontal position; about 300 ft. north of the place of observation set a stone or drive a wooden plug, upon which, by a strongly illuminated pencil or other slender object exactly coincident with the vertical wire, mark a point in the line of sight thus determined; then quickly revolve the vernier plate 180°, repeat the observation, and as before mark a point in the new direction; then the middle point between the two marks, with the point under the instrument, will define on the ground the trace of the vertical plane through Polaris at its eastern or western elongation, as the case may be.

7. By daylight lay off to the east or west, as the case may require, the proper azimuth taken from Table VIII; the instrument will then define the *true meridian*,* which may be permanently marked by monuments for future reference.



144. A reflector, such as is shown in our diagram, will be found useful for illuminating the cross-wires; a lantern held near and to one side of the instrument furnishes the light. Such a reflector can be obtained from any instrument-maker, or the surveyor may have one made of bright tin by his local tinner at a nominal price.

145. To determine the True Meridian by Observation on Polaris at Elongation, with a Plumb-line and Peep-sight.

1. Attach the plumb-line to a support situated as far above the ground as practicable, such as the limb of a tree, a piece of board nailed to a telegraph pole, a house, barn, or other building affording a clear view in a north and south direction.

The plumb-bob may consist of some weighty material, such as a brick, a piece of iron or stone, weighing four to five pounds, which will hold the plumb-line straight and vertical fully as well as one of turned and finished metal.

Strongly illuminate the plumb-line just below its support, by a lamp or candle, taking care to obscure the source of light from the view of the observer by an opaque screen.

* To obtain the magnetic declination, take the magnetic bearing of the true meridian. This bearing is equal in magnitude to the declination; and, if this bearing is east, the declination is *west;* if the bearing is west, the declination is *east.*

2. For a peep-sight, cut a slot about one-sixteenth of an inch wide in a thin piece of board, or nail two strips of tin, with straight edges, to a square block of wood, so arranged that they will stand vertical when the block is placed flat on its base upon a smooth horizontal rest, which will be placed at a convenient height south of the plumb-line, and firmly secured in an east and west direction in such a position that, when viewed through the peep-sight, Polaris will appear about a foot below the support of the plumb-line.

The position may be practically determined by trial the night preceding that set for the observation.

3. About 30 min. before the time of elongation, as given in the tables of elongation, bring the peep-sight into the same line of sight with the plumb-line and Polaris.

To reach elongation, the star will move off the plumb-line to the east for eastern elongation, or to the west for western elongation. Therefore, by moving the peep-sight in the proper direction, east or west as the case may be, keep the star on the plumb-line until it appears to remain stationary, thus indicating that it has reached its point of elongation. The peep-sight will now be secured in place by a clamp or weight, and all further operations will be deferred until the next morning.

4. By daylight, place a slender rod at a distance of 200 or 300 ft. from the peep-sight, and exactly in range with it and the plumb-line; carefully measure this distance.

Take, from Table VIII, the azimuth of Polaris corresponding to the latitude of the station and the year of observation; find the natural tangent of said azimuth and multiply it by the distance from the peep-sight to the rod; the product will express the distance to be laid off from the rod, exactly at right angles to the direction already determined (to the west for eastern elongation, or to the east for western elongation), to a point which, with the peep-sight, will define the direction of the true meridian with sufficient accuracy for the needs of local surveyors.

146. To determine the True Meridian by observing the Transits of Polaris and Another Star across the Same Vertical Plane.

1. A very close approximation to a true meridian may be had by remembering that Polaris very nearly reaches the true meridian when it is in the same vertical plane with the star Delta (δ) in the constellation Cassiopeia. Using the apparatus just described, place the peep-sight in line with the plumb-line and Polaris, and move it to the *west*

as Polaris moves *east*, until Polaris and Delta *appear upon the plumb-line together*, and carefully note the time by a clock or watch; then, by moving the peep-sight, preserve its alinement with *Polaris* and the *plumb-line* (paying no further attention to the other star); at the expiration of the short interval of time derived from the table below, the *peep-sight* and *plumb-line* will define the *true meridian*, which may be permanently marked for further use.

2. This method is practicable only when the star Delta is *below* the pole during the night; when it passes the meridian above the pole it is too near the zenith to be of service, and in this case the star Zeta (ζ), the last star but one in the tail of the Great Bear, may be used instead.

Delta (δ) Cassiopeiæ is on the meridian below Polaris and the pole at midnight about April 10, and is, therefore, the proper star to use at that date, and for some two or three months before and after.

Six months later the star Zeta (ζ), in the tail of the Great Bear, will supply its place, and should be used in precisely the same manner.

The method given in this article for finding the true meridian cannot be used with advantage at places below about 38° north latitude, on account of the haziness of the atmosphere near the horizon.

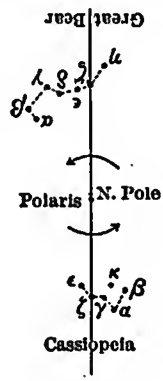


Fig. 49

The diagram (Fig. 49), drawn to scale, exhibits the principal stars of the constellations Cassiopeia and Great Bear, with Delta (δ) Cassiopeiæ, Zeta (ζ) of the Great Bear, and Polaris on the meridian, represented by the straight line; Polaris being at *lower* culmination.

This method is given in Lalande's "Astronomy," and was practised by A. Ellicott in 1785 on the Ohio and Pennsylvania boundary.

The following table, giving the interval of time before Polaris will be exactly on the meridian, is to be used in this method:

		Annual Increase
For Zeta (ζ) Ursæ Majoris in 1912	+ 7.1 minutes	0.40 minute
For Delta (δ) Cassiopeiæ in 1912	+ 8.2 "	0.42 "

The foregoing methods for the determination of the true meridian are excellent in themselves when available, as they answer the requirements of the surveyor and give results with all desirable precision. They do not require an accurate knowledge of the time, and

herein lies their principal advantage. The relative motion of the stars employed, when near the meridian and the unchangeable azimuth of Polaris at elongation (so far as the surveyor is concerned), indicate with sufficient exactness the moment when the observation should be made. Stormy weather, a hazy atmosphere, or the presence of clouds may interfere with or entirely prevent observation when the star is either at elongation or on the meridian, and both events sometimes occur in broad daylight or at an inconvenient hour of the night. There is, however, a simple method applicable *at any time* (provided Polaris is visible) which can often be used by the surveyor when other methods fail. For an account of this method the student is referred to Johnson's "Theory and Practice of Surveying," or to the "Manual of Instructions" (United States Land Office) already mentioned.

147. Latitude. — Remembering that the latitude of a place is equal to the altitude of the pole, the surveyor may determine his latitude as follows:

Simply observe the altitude of a circumpolar star at upper or lower culmination, and correct this altitude for the pole distance of the star and for refraction.

Let $\phi =$ latitude, $r =$ refraction,
$d =$ polar distance, $h =$ altitude;

then
$$\phi = h \mp d - r,$$
the minus sign being used for upper and the plus sign for lower culminations.

The refraction r may be obtained from Table I, page 36; the following table gives d, if Polaris is used:

TABLE X

POLE DISTANCE (90° – DECLINATION) OF POLARIS

1914	1915	1916	1917	1918	1919	1920
1° 9′.2	1° 8′.9	1° 8′.6	1° 8′.3	1° 8′.0	1° 7′.6	1° 7′.4

The values given are for the first of January; for intermediate years, interpolate. For other months than January, *add* to the pole distances found for January the following corrections:

February, 0′.1; March, 0′.2; April, 0′.3; May, 0′.5; June, 0′.6; July, 0′.7; August, 0′.6; September, 0′.5; October, 0′.3; November, 0′.2; December, 0′.1.

CHAPTER IV

COMPUTATION OF AREAS

148. The *Difference of Latitude* (which, for brevity, we shall call the "latitude") of a course is the perpendicular distance between the east and west lines passing through the beginning and end of the course.

The *Difference in Longitude* (called the "departure") of a course is the perpendicular distance between the meridians passing through the extremities of the course.

149. The "latitude" is called a *northern* or a *southern*, according as the course runs north or south; the "departure" is an *easting* or a *westing*, according as the course runs east or west.

A northern is considered positive and has the sign +; a southern is considered negative and has the sign −. Similarly, an easting is *plus*, and a westing is *minus*.

The *meridian distance* of a point is its perpendicular distance from any assumed meridian. Thus, if *NS*, Fig. 50, is the meridian of reference, *BE*, perpendicular to *NS*, is the meridian distance of *B*.

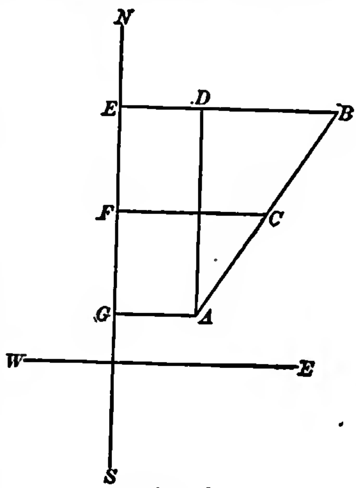


FIG. 50

The *meridian distance of a line* is the meridian distance of its *middle* point, and is east or west according as the point lies east or west of the assumed meridian.

In the figure, *FC* is the meridian distance of the line *AB*.

150. If the length and bearing of a course are given, its latitude and departure may be found by the following formulæ:

Let AB be the course; then, AD being parallel to the meridian,

$$\text{Latitude}^* = \text{L.} = AD = AB \cos DAB,$$

$$\text{Departure} = \text{D.} = DB = AB \sin DAB;$$

that is,

$$\text{Latitude} = \text{course} \times \text{cosine of its bearing},$$

$$\text{Departure} = \text{course} \times \text{sine of its bearing}.$$

For instance, to get the latitude and departure of AB in example, page 91, bearings as given on page 63 having been adjusted, we have

$$\text{L.} = 50.04 \times \cos 75° \, 28',$$

$$\text{D.} = 50.04 \times \sin 75° \, 28'.$$

Taking the values of the cosine and sine from the Table of Natural Signs,† Table XIX, we have

$$\text{L.} = 50.04 \times 0.25094 = 12.56,$$

$$\text{D.} = 50.04 \times 0.96800 = 48.44.$$

Similarly, for course BC, we have

$$\text{L.} = 53.72 \times \cos 10° = 53.72 \times 0.98481 = 52.90,$$

$$\text{D.} = 53.72 \times \sin 10° = 53.72 \times 0.17365 = 9.33.$$

151. The Traverse Table and its Use. — To save the labor of making the calculations of the preceding article for each course, a table called a *Traverse Table* has been prepared from such formulæ giving the latitude and departure of certain distances for certain angles. These tables are usually calculated to every 15 minutes; but as so much surveying is now done with the transit, by means of which bearings correct to 2′ can be obtained, traverse tables are becoming antiquated.‡ The Table of Natural Sines and Cosines (Table XIX) will answer the purpose of a traverse table, the *sine* column giving *departures* for the unit distance, and the *cosine* column giving the *latitudes*. To adapt the table to this use, the sine and cosine columns might be headed "departure for distance unity," and "latitude for distance unity," respectively. Using it thus, the result is obtained exactly as in Art. 150. No separate traverse table is given in this book.

* Really "difference of latitude," see Art. 148.

† Or the calculation can be made by logarithms, see Art. 176.

‡ A traverse table, computed for every minute of arc and for distances from 1 to 10, by Major-General J. T. Boileau, F.R.S., is published by D. Van Nostrand Co., New York. It is necessarily bulky and expensive. In the opinion of the author very little, if any, labor is saved by using a traverse table.

BALANCING THE SURVEY

152. Error of Closure. — It is evident that in going completely around a field back to the starting-point, we have gone just as far north as south, and just as far east as west; therefore, if there are no errors, we must have the sum of the northings = sum of the southings, and the sum of the eastings = sum of the westings.

Stations	Bearings	Dists.*	Latitudes		Departures		Cor. †		Balanced		D. M. D.	Areas	
			N. +	S. −	E. +	W. −	Lat.	Dep.	Lat.	Dep.		+	−
A	S. 75° 28′ W.	50.04		12.56		48.44	1	6	−12.57	−48.50	+ 67.30		845.9610
B	N. 10° W.	53.72	52.90			9.33	1	7	+52.89	− 9.40	+ 9.40	497.1660	
C	N. 86° 35′ E.	21.84	1.30		21.80		0	3	+ 1.30	+21.77	+ 21.77	28.3010	
D	S. 80° 30′ E.	35.92		5.93	35.43		1	4	− 5.94	+35.39	+ 78.93		468.8442
E	S. 1° 15′ E.	35.68		35.67	0.78		1	4	−35.68	+ 0.74	+115.06		4105.3408
		197.20	54.20	54.16	58.01	57.77						525.4670	5420.1460
			54.16		57.77								525.4670
			.04		.24								2)4894.6790

Error of closure $= \frac{\sqrt{4^2+24^2}}{19720} = \frac{21.33}{19720}$, $= 1$ in 802.

Area $= 2447.3395$ sq. rd. $= 15$ A. 1 R. 7 sq. rd.

These two relations furnish a means of testing the accuracy of the field work. In our example (see tabulated view above) we find that the northings exceed the southings by .04 of a rod, and the eastings exceed the westings by .24. The meaning of this is that there is a gap between the end of the last course and the beginning of the first (our diagram, Fig. 44, is not drawn on a scale large enough to show this), and that the line filling this gap (completing the polygon) has a south latitude = .04, and a west departure = .24, its length being $= \sqrt{(.04)^2 + (.24)^2} = .2433$. The ratio of this length to the perimeter of the field is called the error of closure. Hence, in this example, error of closure $= \frac{24.33}{19720}$, or 1 in 802.

This error is not large for compass work. The limit of error to be allowed depends upon the importance of the survey. Professor Johnson ‡ says "the error of closure for ordinary rolling country should not be more than 1 in 300. In city work it should be less than 1 in 1000, and should average less than 1 in 5000."

Unless the land surveyed is of very little value, the surveyor

* Here distances are given in rods (or poles). † Corrections.

‡ "Theory and Practice of Surveying," J. B. Johnson.

should aim to make the error very much less than 1 in 300; and yet many county surveyors are so careless in keeping their instruments in order and insisting on careful horizontal chaining, that one often finds the error in the survey of a fertile, valuable farm much greater than this limit. Of course, getting the exact area is usually a small matter in comparison with locating the bounding lines exactly where they belong.

153. Rules for Balancing the Survey. — Having found the errors in latitude and departure, the next step toward getting the area is to "balance" the survey, that is, to distribute the error. We give two rules for this.

RULE 1. — *The sum of all the courses is to each particular course as the whole error in latitude (departure) is to the correction of the corresponding latitude (departure)*, each correction being so applied as to diminish the whole error.

RULE 2. — *The arithmetical sum of all the latitudes (departures) is to any one latitude (departure) as the whole error in latitude (departure) is to the correction of the corresponding latitude (departure)*, each correction being so applied as to diminish the whole error.

The *first rule* is used when it is assumed that the error is as much due to faulty bearings as to erroneous chaining, as is usually the case in needle-compass work. The *second rule* is based on the assumption that the error is due almost entirely to errors in chaining, and this rule should be used if the lines are run with a solar attachment or as a traverse with a transit.

In our example we use Rule 1, and the error in latitude (.04) is to be so distributed that a part is to be added to the southings, and the remaining part subtracted from the northings. Similarly, for the error of .24 in departure, the correction to be applied to the westings is additive, that to the eastings is subtractive. In columns 8 and 9 the corrections are given, and in the 10th and 11th columns the corrected latitudes and departures are given, only one column being devoted to each, and the proper signs given. The corrections must be so applied that the sum of the negative latitudes (departures) *exactly* equals the sum of the positive latitudes (departures).

Theoretically the "corrections" are obtained by the proportions:

$$\text{For latitude}\begin{cases}19720:5004=4:x, \text{ or } x=1.0=1\\ 19720:5372=4:x, \text{ or } x=1.1=1\end{cases}$$

$$\text{For latitude}\begin{cases}19720 : 2184 = 4 : x, \text{ or } x = 0.5 = 0\\ 19720 : 3592 = 4 : x, \text{ or } x = 0.7 = 1\\ 19720 : 3568 = 4 : x, \text{ or } x = 0.7 = 1\end{cases}$$

Similar proportions for departure give the corrections 6, 7, 3, 4, 4, taken to the nearest hundredth of a rod. Practically, in an example like this, where the error is not great, the surveyor soon learns to put down the corrections mentally after glancing over the lengths of the courses. In most cases no two computers will distribute the error exactly alike, but the resulting areas will not differ much.

154. Sometimes it is advisable to attribute a larger part of the error to one or more courses than their proportional share. For instance, if, in our example, the course AB was hilly and it was chained through brush, while the other courses were all on level ground, free from undergrowth, it might be legitimate to apply all of the error to the latitude and departure of that course, especially if in addition to the uncertain chaining there was any reason to suppose the bearing of that course doubtful. Sometimes there will be a course on which it seems likely that there is twice as much chance of error as on some other, while on still other courses there is perhaps three times the chance of error. Courses treated in this way are said to be "weighted" and to have the weights 2, 3, etc. In any case the weight a course should have depends upon the judgment of the surveyor.

155. When the error is excessive, a re-survey is necessary. Before making the second survey, go over the balancing carefully in order to be sure that the mistake is in the field and not in the office. A careful examination of the errors in latitude and departure will often be helpful in locating the particular course where the larger part of the error probably was made, thus rendering it unnecessary to re-survey more than a portion of the boundary.

DOUBLE MERIDIAN DISTANCES

156. Having balanced the work, the next step is to calculate the double meridian distance (D. M. D.) of each course. While, for this purpose, any meridian may be chosen, it will be found more convenient to take as our reference line the meridian through either the most westerly or the most easterly station, as the D. M. D.'s will then all have the same sign. In the example here given we use the

meridian through the most westerly station. A hurried examination of the notes, even when one is not familiar with the field, will usually determine the most westerly station.

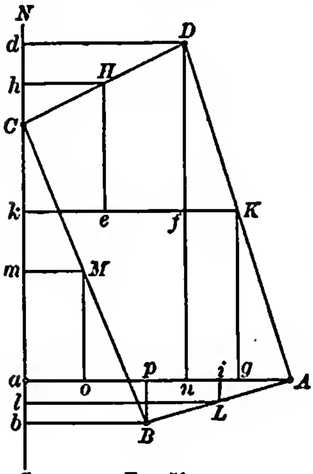


FIG. 51

To deduce rules for computing the D. M. D. of any course, we use Fig. 51, taking NS as our reference meridian. Obviously,* we have

$$2\,hH = dD.$$

$$2\,kK = 2\,ke + 2\,ef + 2\,fK = 2\,hH + dD + nA.$$

$$2\,lL = 2\,ai = 2\,ag + 2\,gA - 2\,iA = 2\,kK + nA - pA.$$

$$2\,mM = 2\,ao = 2\,ai - 2\,pi - 2\,op = 2\,lL - pA - bB.$$

Hence, remembering that east departures are +, and west −, we have the *rules :*

The D. M. D. of the first course is equal to its departure.

The D. M. D. of the second course is equal to the D. M. D. of the first course plus its departure, plus the departure of the second course.

The D. M. D. of any course is equal to the D. M. D. of the preceding course plus the departure of that course, plus the departure of the course itself.

NOTE. — The D. M. D. of the first course has the same value and the same sign as the departure of that course, and the D. M. D. of the last course should have the same value and opposite sign of the departure of that course. This serves as a check on the work. Thus in the example, of which a tabulated form is given on page 91, C being the most westerly course, the D. M. D. of CD ($= +21.77$) is first obtained, and then the rest in order by the rules, the D. M. D. of the last (BC) being $+9.40$, which is equal to the departure of BC but has the opposite sign.

157. Area. — If $S =$ area $ABCD$ (Fig. 51), it is evident that $S =$ the area of the entire figure $dDABbd$ less the sum of the areas of the two triangles CdD and CbB, or, numerically,

$$S = dDAa + aABb - (CdD + CbB).$$

Therefore

$$2\,S = (dD + aA) \times Dn + (aA + bB) \times pB - Cd \times dD - bC \times bB.$$

* H, K, L, and M being the middle points of CD, DA, AB, and BC respectively.

Now
$$dD + aA = \text{D. M. D. of } AD,$$
$$aA + bB = \text{D. M. D. of } AB,$$
$$dD = \text{D. M. D. of } CD,$$
$$bB = \text{D. M. D. of } BC,$$

and all these values are positive; Cd and bC are also positive, while Dn and pB are negative.

Hence

$$2\,S = -[(dD + aA) \times Dn + (aA + bB) \times pB + Cd \times dD + bC \times bB],$$

the quantities to be taken with their algebraic signs.

That is, *twice the area of the field is equal to the algebraic sum of the products of the double meridian distances of the courses by their corresponding latitudes*, this sum being negative if the field is kept on the right in making the survey, and positive, if on the left.*

In our illustrative example, page 91, the sum of the plus areas is found to be 525.4670 sq. rd. and the sum of the minus areas 5420.1460; their difference, 4894.6790, is double the area of the field. Hence the area = 2447.3395 sq. rd. = 15 A. 1 R. 7 sq. rd.

158. As a further illustration, we add another example, for a plot of which see Fig. 51. In this example the error of closure (1 in 468) is much greater than in the example given on page 91.

Station	Magnetic Bearing	Dist. (ch.)	Latitude		Departure		Cor.		Balanced		D.M.D.	Areas	
			N. +	S. −	E. +	W. −	Lat.	Dep.	L.	D.		+	−
A	S. $74\frac{3}{4}°$ W.	8.86		2.33		8.55	1	1	− 2.34	−8.56	+22.68		53.0712
B	N. $21\frac{1}{2}°$ W.	19.20	17.87			7.03	3	3	+17.84	−7.06	+ 7.06	125.9504	
C	N. 64° E.	10.80	4.73		9.71		1	2	+ 4.72	+9.69	+ 9.69	45.7368	
D	S. $16\frac{1}{2}°$ E.	21.05		20.19	5.97		3	4	−20.22	+5.93	+25.31		511.7682
		59.91	22.60	22.52	15.68	15.58						171.6872	564.8394
			22.52		15.58								171.6872

Error in L. = .08   .10 = error in D.   2) 393.1522

196.5761

Error in closure $= \dfrac{\sqrt{8^2 + 10^2}}{5991}$, or 1 in 468.

Area = 196.576 sq. ch. = 19 A. 2 R. 25 sq. rd.

SUPPLYING OMISSIONS

159. It may happen that on account of the inaccessibility of parts of the field, or for other reasons, some of the field notes

* It is evident, therefore, that the *sign* of the resulting area has no significance, except as it indicates the direction of the field work.

cannot be obtained. In general, two omissions may be supplied. We shall consider four cases in which the omitted parts can be found by calculation.

FIRST. — *The bearing and length of one course omitted.*

SECOND. — *The bearing of one course and the length of another omitted, when the courses are: (a) contiguous, (b) separated.*

THIRD. — *The bearings of two courses omitted, when they are: (a) contiguous, (b) separated.*

FOURTH. — *The lengths of two courses omitted, when they are: (a) contiguous, (b) separated.*

All four problems may be solved by algebraic equations involving trigonometric functions; but the following trigonometric solutions are perhaps simpler.

160. FIRST CASE. — Suppose the bearing and length of CD in field on page 95 are omitted. Find the latitudes and departures of the other courses. Now, as in a complete survey the sum of the northings must be equal to the sum of the southings, and the sum of the eastings to the sum of the westings, if we take the difference between the sum of the northings and the sum of the southings, in this case $= 22.52 - 17.87 = 4.65$, a northing, and the difference between the sum of the eastings and the sum of the westings, in this case $= 15.98 - 5.97 = 9.61$, an easting, these numbers (supposing there is no error in the field work) give the L. and D. respectively of the omitted course; that is (Fig. 51),

$$Cd = +4.65, \quad dD = +9.61,$$

and, from the right-angled triangle CdD, we compute the length and bearing of CD as follows:

$$\tan dCD = \frac{9.61}{4.65} = 2.0666.$$

$$\therefore \ dCD = 64° \, 10' \, 30'',$$

or the bearing of

$$CD = \text{N. } 64° \, 10' \text{ E.}$$

Again,
$$dD = CD \sin dCD.$$

$$\therefore \ CD = \frac{9.61}{.9001} = 10.67 \text{ ch.}$$

It will be noticed that this bearing and length of CD do not coincide with the values given in the example. This difference is largely owing to the fact that all the error made in the field work has been concentrated on this one course. For this reason it is always best to measure all the courses and read all the bearings; for otherwise there is no means of discovering what error has been made in the field notes.

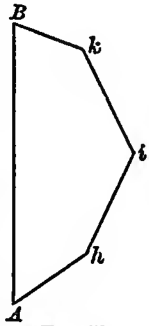


FIG. 52

The method of this article gives the means of obtaining the length and direction of a course which, owing to some obstacle, cannot be directly measured. For example, suppose that AB is a course in a survey that, owing to buildings and trees on the line, cannot be directly measured. Run a traverse (the fewer the sides the better) $AhikB$ from the beginning A to the end B of AB, getting the length and bearing of each side. Then compute, by the method just given, the length and bearing of AB.

161. SECOND CASE. — (*a*) The defective courses contiguous. — In the survey of a field $ABCDEF$, the incomplete notes of which are given below, suppose the length of DE and the bearing of EF are omitted.

STATIONS	BEARINGS	CHANGED BEARINGS	DISTS. (ch.)	LATITUDES		DEPARTURES	
				N.	S.	E.	W.
A	N. 85° W.	West	48	0			48.00
B	S. 76° 30′ W.	S. 71° 30′ W.	5.18		1.64		4.91
C	N. 8° 30′ W.	N. 13° 30′ W.	34	33.13			7.65
D	N. 5° E.	North					
E			345.41				
F	S. 85° 20′ W.	S. 80° 20′ W.	288.91		48.51		284.81

Suppose the meridian line turned through an angle of 5° clockwise, and change the bearings of all the courses accordingly. The object of this is to make the course whose *length is missing* coincide with the meridian line, thus making its departure zero. The shape and dimensions of the field are evidently not altered by this supposition. Get the L. and D. of all the known courses, using the changed bearings. Now, since the D. of DE is zero, the difference between the sum of the east D.'s and the sum of the west D.'s of the known courses is the D. of the course EF. In this case, as

all the known D.'s are west, their sum, 345.37, is the D. of the course *EF*. We next find the bearing of *EF*,

$$\text{sine (bearing)} = \frac{\text{departure}}{\text{distance}} = \frac{345.37}{345.41} = .99988,$$

which gives (see Table XIX) bearing = 89° 7′; that is, N. 89° 7′ E., or S. 85° 53′ E. with reference to the original meridian. As the value of the angle is obtained from the sine, and the sine of an angle is the same as the sine of 180° minus the angle, there is an ambiguity here, which, however, the surveyor's knowledge of the field will usually enable him to remove.*

Next, to get the L. of *EF*, we use the formula

$$\text{L.} = \text{distance} \times \cos(\text{bearing}) = 345.41 \times .01542 = 5.32,$$

and the length of *DE*, which is its latitude, is at once obtained by subtracting the sum of the northings from the sum of the southings, thus —

$$\begin{aligned}\text{Distance } DE &= 33.13 + 5.32 - (1.64 + 48.51) \\ &= 38.45 - 50.15 = 11.70 \text{ ch.}\end{aligned}$$

(*b*) The defective courses separated.

It is evident that the method just employed is applicable here. We have only to change all the bearings in such a way as to make the course the length of which is omitted run *north*, and proceed as in (*a*).

162. THIRD CASE. — The bearings of two sides being omitted.

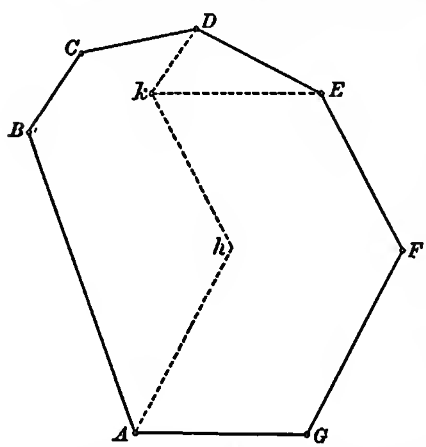


FIG. 53

(*a*) The defective courses contiguous. Find the L.'s and D.'s of the other sides, and then, as in the first case, find the length and bearing of the line joining the extremities of the deficient sides. Then, in the triangle thus formed, we have the three sides from which to find the angles and thence the bearings.

(*b*) The defective courses separated. Change the places of the sides so as to bring the defective ones next to each other.

* In this particular case, since the angle is so near 90°, the surveyor, even if he has a fair knowledge of the field, may be in doubt whether the course is N. E. or S. E.

Thus (Fig. 53) in the field $ABCDEFG$, suppose the bearings of DE and GA to be missing. Draw Ah parallel and equal to GF, hk parallel and equal to FE, then draw kD and kE. kE will evidently be parallel and equal to AG. In the figure $ABCDkhA$, everything is known except Dk. Calculate, as in first case, the length and bearing of Dk. Then in the triangle DkE, the three sides are known, and we can compute the angles, and thence the bearings of DE and Ek (or GA), which are required.

163. Fourth Case.—The lengths of two courses omitted, when they are (a) contiguous, (b) separated.

The method by changing the meridian (Art. 161) may be advantageously employed here; or else the method of the last article (162).

EXAMPLES

Supply the missing parts in the field notes of the surveys given below.

1

Stations	Bearings	Distances (rd.)
A	S. 68° E.	280
B	N. 9° E.	—
C	N. 68° W.	280
D	—	132
E	S. 22° W.	68

2

Stations	Bearings	Distances (rd.)
A	S. 6° E.	60
B	—	55.40
C	N. 61° W.	81.28
D	—	121.72

3

Stations	Bearings	Distances (ch.)
1	N. 15° E.	80
2	N. 37° 30′ E.	—
3	East	30
4	S. 11° E.	50
5	South	54
6	West	40
7	S. 36° 30′ W.	—
8	N. 38° 15′ W.	34

4. Compute the areas of (1), (2), and (3), and draw accurate plot of each after supplying the missing parts.

164. Coördinate Method of computing Areas. — This method is useful in obtaining the areas of large tracts of land made up of smaller tracts. It frequently happens that a syndicate or company buys up a number of adjacent farms in order to secure the iron ore or coal that they contain, or for some other purpose. If every corner is well established, this is a convenient way of getting the total area.

The bearings and distances having been determined, we plot the tract and then draw our coördinate axes at right angles to each other on the paper.

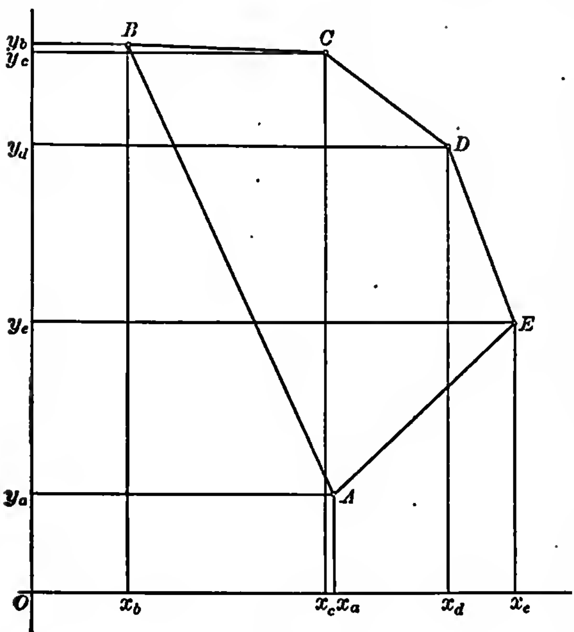


FIG. 54

It is best, in order to avoid change of sign, to draw the axes so that the entire figure shall be contained in one quadrant. Then draw perpendiculars from each corner to the two lines (axes) respectively, and, using the same scale, measure these perpendicular distances.

For illustration, take an example the field notes of which are given on page 106, Ex. 10. We first plot the tract carefully, Fig. 54, and draw the axes OX and OY,* the former running east and west, one chain south of station A, the latter running north and south, one chain west of station B. Now it is evident that, letting S represent the area, the area of $ABCDE$ is

$$S = y_aAEy_e + y_eEDy_d + y_dDCy_c + y_cCBy_b - y_aABy_b.$$

$$\therefore\ 2S = (x_a + x_e)(y_e - y_a) + (x_e + x_d)(y_d - y_e)$$

$$+ (x_d + x_c)(y_c - y_d) + (x_c + x_b)(y_b - y_c) - (x_a + x_b)(y_b - y_a),$$

* These lines are called coördinate axes, and distances measured parallel to the x-axis (the E. and W. line in this case) are called *abscissæ*, and those parallel to the y-axis (the N. and S. line) *ordinates*.

or, rearranging and dividing by 2,

$$S = \tfrac{1}{2}\left[x_a(y_e - y_b) + x_b(y_a - y_c) + x_c(y_b - y_d) + x_d(y_c - y_e) + x_e(y_d - y_a)\right],$$

or

$$S = -\tfrac{1}{2}\left[y_a(x_e - x_b) + y_b(x_a - x_c) + y_c(x_b - x_d) + y_d(x_c - x_e) + y_e(x_d - x_a)\right].$$

These equations furnish the following rule for finding the area from the rectangular coördinates of the corners:

Multiply the abscissa (ordinate) of each corner by the difference between the ordinates (abscissæ) of the two adjacent corners, making the subtraction in the same direction around the field, and take the half-sum of these products.

The form of reduction, for our example, Fig. 54, is as follows:

Stations	Abscissæ (x)	Ordinates (y)	Difference between Alternate Ordinates	Double Areas
A	3.122	1.000	− 2.927	− 9.1381
B	1.000	5.730	− 4.674	− 4.6740
C	3.060	5.674	+ 1.067	+ 3.2650
D	4.364	4.663	+ 2.871	+ 12.5990
E	5.051	2.803	+ 3.663	+ 18.5018

$$
\begin{aligned}
\text{Plus areas} &= 34.3658\\
\text{Minus areas} &= \underline{13.8121}\\
&\ 2)\underline{20.5537}\\
\therefore\ \text{Area} &= 10.2768 \text{ sq. ch.}\\
&= 1.028 \text{ A.}
\end{aligned}
$$

PLOTTING

165. Some description of the drawing instruments necessary for making a map or plot of a field has been given (Arts. 102–105). It is beyond the scope of this work to enter minutely into the various methods of drawing a plot, but a few suggestions and explanations may be helpful. For illustration, take the example, Fig. 44, the corrected notes of which are given in the reduction form on page 91.

166. Using the *bearings* and *lengths* of the courses, we should proceed as indicated in Art. 105, if a circular protractor is employed, measuring the distances by means of a triangular scale, or other

measure. Corners, or intersections of adjacent lines, are often marked by a dot with a little circle around it, as is done in Fig. 44, the lines being drawn up to the small circle. The real corner is defined in this way better than if the lines were allowed to intersect each other.* The direction of the magnetic or true meridian, or preferably both, should be given on the plot, and also the scale.

Instead of using a protractor, the angles may be laid off by means of a Table of Chords (Table XV). An example will best explain the use of this table.

Suppose it is required to lay off, at the point A, a line making an angle of 20° 10′ with AB. From A as a centre, with some convenient unit radius describe an arc. From the table we find that the chord corresponding to 20° 10′ is 0.3502. Hence from B as a centre, with radius = .35, describe an arc intercepting the former arc at C, and draw AC; BAC will be the required angle. For good results a large scale must be used. This method by chords will not give the same degree of precision as that obtained by the use of a good vernier protractor.

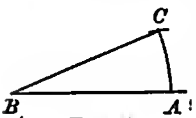


FIG. 55

167. Using the deduced *latitudes* and *departures*,† the survey may readily be plotted by getting the distances of each corner from two lines at right angles to each other, the one coinciding with an east and west line, the other running north and south. For simplicity, we shall consider our lines of reference drawn through C, the most westerly station, using the example given on page 91. The work is very much simplified by the use of cross-section paper as in Fig. 56, the lines being supposed to run east and west and north and south respectively.

Rule three columns; one for stations, the second for total latitudes, and the third

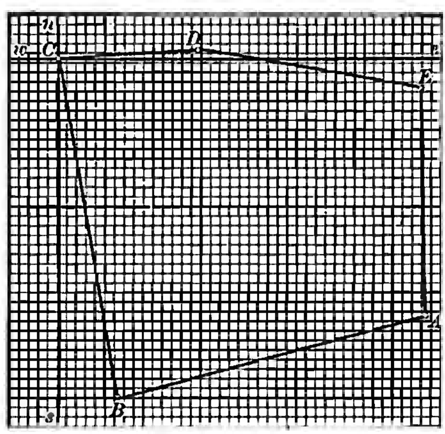


FIG. 56

* Because it is difficult to determine the exact intersection of two lines, especially if they make a small angle with each other.

† The values of these *after* "balancing" had best be taken.

for total departures. Fill the last two columns by beginning at *C*, and adding (algebraically) the latitudes of the following stations. Do the same for the departures, and write down the results as follows:

Stations	Total Latitudes from (*C*)	Total Departures from (*C*)
C	0.00	0.00
D	+ 1.30	+21.77
E	− 4.64	+57.16
A	−40.32	+57.90
B	−52.89	+ 9.40

As a check on the work, it may be noticed that the total latitude and total departure of the last course are equal in value to the latitude and departure of the first course, and have opposite signs. Using the values found above, we locate the points *D*, *E*, *A*, *B*, and draw the lines *CD*, *DE*, *EA*, *AB*, and *BC*.

This is a rapid, easy, and accurate method of making the plot.

168. Copying. — The most satisfactory method of copying is by the *blue print* process. This requires that the final drawing be made on tracing cloth (or paper). By exposure to the sunlight, an exact copy of the tracing is taken on paper previously prepared.

This prepared paper and the blue print frames are sold by instrument makers, whose hand-books or catalogues usually give a full explanation of the process. In making the tracing, the scale should be drawn, as well as stated; for, as the paper on which the copy is made has to be washed in water after exposure to the sun, it always shrinks, and distances can be taken off accurately only by a scale drawn on the tracing.*

In the absence of a blue print outfit, it is possible to copy the drawing by means of carbon paper placed under the sheet on which the drawing is made, with its carbon side resting on the sheet upon which the copy is to be made.

169. Graphic Method of computing Areas. — Many surveyors compute the areas of land by plotting the survey, drawing lines dividing the polygon into triangles (or other simple figures), and then obtaining by scale the lengths of one side of each triangle and the perpendicular dropped upon it from the opposite vertex.

* It may reasonably be supposed that such a scale has contracted proportionally to the rest of the drawing.

The formula, area $= \frac{1}{2}$ base $\times$ the altitude, gives the area of each triangle. To obtain good results, the plot should be drawn most carefully and to as large a scale as practicable. Owing to lack of care in making the drawing, the results are often unreliable, and at best they are not as accurate as when the method of calculation by double meridian distances is used.

As an illustration, the field, the plot of which is given as Fig. 44, has been divided by the dotted lines into triangles and the altitudes of these triangles have been drawn. Using the scale of the drawing, we find $AD = 55$, $Bk = 45$, $Ei = 23$, $BD = 55.6$, $Ch = 20.8$. Hence

$$\begin{aligned}
\text{Area } ADE &= \tfrac{1}{2} \times 55 \times 23 = 632.5 \\
\text{Area } ADB &= \tfrac{1}{2} \times 55 \times 45 = 1237.5 \\
\text{Area } BDC &= \tfrac{1}{2} \times 55.6 \times 20.8 = 578.84 \\
\text{Total area} &= 2448.84 \text{ sq. rd.} \\
&= 15 \text{ A. } 1 \text{ R. } 8 \text{ sq. rd.,}
\end{aligned}$$

which coincides very nearly with the result obtained on page 91.

EXAMPLES*

1. A tract of land is described as follows: Beginning at the Valley Pike and running with D. W. Barton N. 50¼° W., 220.20 poles to a Black Oak stump in the lane, then with said Barton N. 45½° E., 173.21 poles to a stone, corner to said Barton in R. L. Baker's line, then with Baker S. 44¾° E., 139 poles, then S. 48½° E., 22 poles to the pike, then with it S. 7° W., 44 poles, and S. 30° W., 127 poles to the beginning, containing two hundred and five acres and eighteen square poles.

Given under my hand this 11th day of August, 1854.

(Signed) Mahlon Gore, S.F.C.

Compute the area of the above tract and plot it.

Compute, by the double meridian distance method, the area of the following surveys, and in each case find the error of closure and draw the plot.

* A majority of these examples, as well as those given as exercises under Transit Surveying, are actual surveys made by the author's classes. Some are old surveys, and the error of closure is often excessive; but in practice the surveyor will frequently meet with similar inexact surveys.

2

Stations	Magnetic Bearings	Distances (ch.)
A	S. 65° W.	3.48
B	S. 58¾° W.	2.20
C	S. 69¼° W.	19.12
D	N. 22° 15′ W.	4.29
E	N. 67° 30′ E.	6.83
F	N. 67° 20′ E.	18.04
G	S. 22° 15′ E.	4.43

3

Stations	Bearings	Distances (ch.)
A	S. 29° 45′ W.	11.64
B	N. 55° 58′ W.	3.80
C	N. 32° 45′ E.	3.86
D	N. 26° 22′ E.	4.00
E	N. 56° 10′ W.	13.08
F	N. 70° 5′ E.	3.97
G	S. 58° 25′ E.	14.29

4

Stations	Bearings	Distances (ch.)
1	N. 16° 30′ E.	22
2	N. 82° E.	19.60
3	S. 17° E.	24
4	S. 37° W.	22
5	N. 49° W.	25.20

5

Sta.	Magnetic Bearings	Distances (ch.)	Sta.	Magnetic Bearings	Distances (ch.)
A	N. 12° 15′ W.	33.65	H	S. 64° 9′ W.	28.79
B	N. 65° 15′ E.	83	I	N. 45° 15′ W.	3.07
C	S. 13° 30′ E.	27.25	K	N. 38° E.	12.58
D	S. 0° 45′ E.	37.95	L	N. 23° 45′ W.	6.95
E	S. 70° W.	48.41	M	N. 65° 15′ E.	37.55
F	S. 74° 43′ W.	45.50	N	N. 85° E.	8.00
G	S. 70° 24′ W.	2.80	O	N. 14° W.	4.47

Ans. 546.84 A.

6

Sta.	Bearings	Distances (rd.)	Sta.	Bearings	Distances (rd.)
1	S. 2° E.	16.20	9	S. 58½° W.	4.76
2	S. 55½° E.	6.24	10	S. 86¾° W.	17.08
3	S. 6° W.	5.32	11	S. 86° W.	41.76
4	S. 84½° W.	14.72	12	N. 10½° W.	16.48
5	S. 9° E.	3.12	13	N. 78½° E.	16.80
6	S. 79½° W.	10.16	14	N. 11¼° W.	22
7	S. 7½° W.	13.12	15	N. 55½° E.	18.52
8	S. 38½° W.	9.80	16	N. 84° E.	64.96

7

Sta.	Bearings	Distances (ft.)
A	N. 68° E.	137
B	S. 17° 28′ E.	268
C	S. 72° 45′ W.	127.5
D	N. 19° 30′ W.	258

8

Sta.	Bearings	Distances (rd.)
1	N. 49° 10′ W.	12.50
2	N. 18° 25′ E.	17.95
3	S. 49° 10′ E.	12.50
4	S. 18° 25′ W.	17.95

9

Sta.	Bearings	Distances (poles)	Sta.	Bearings	Distances (poles)
A	N. 52¼° E.	56	F	N. 29° E.	19.36
B	N. 72° E.	6.68	G	N. 21° W.	3.84
C	N. 51° E.	4.84	H	N. 55° W.	297.92
D	N. 40° E.	13.24	I	S. 36° W.	147.67
E	N. 47° E.	19	K	S. 61° E.	279.24

10

Stations	Magnetic Bearings	Distances (ch.)
A	N. 24° 10′ W.	5.19
B	S. 88° 15′ E.	2.06
C	S. 52° 15′ E.	1.65
D	S. 20° 15′ E.	1.98
E	S. 47° W.	2.64

11. A field is bounded as follows: (1) N. 0° 30′ W., 30.24 poles; (2) N. 66½° E., 62 poles; (3) S. 28° 30′ E., 41.12 poles; (4) S. 67° W., 17.56 poles; (5) S. 14° E., 23 poles; (6) notes omitted. Supply the bearing and length of the missing course, and compute the area of the field.

12. In some convenient field, drive a stake to represent the point "A," and starting at this station run out the boundary of a field, of which the following are the field notes:

Stations	Magnetic Bearings	Distances (ft.)	Station	Magnetic Bearings	Distances (ft.)
A	S. 80° 15′ E.	310	D	N. 79° 20′ W.	221.8
B	S. 21° 19′ W.	225.6	E	N. 2° 10′ E.	345.4
C	S. 47° 22′ W.	290.7	F	N. 69° 53′ E.	205.5

Note.—This is a good exercise for the student. It is just what often has to be done in running old lines (see Chapter III).

13. Suppose that when the field notes in Example 12 were taken, the declination of the needle was 4° 30′ E., but now the declination is 2° 45′ E., a difference of 1° 45′. Change all the bearings by this amount, and beginning at the same stake as in Example 12, run out the boundary, using the changed bearings, and plant stakes at each corner. Compare the new positions of the corners with the old. Has the area been changed?

14. With the needle-compass run a line 40 chains long, N. 20° E.; starting at the same point run a line 40 chains, N. 20° 10′ E., and measure the distance between the ends of the two lines.

CHAPTER V.

TRANSIT SURVEYING*

I. FIELD WORK AND COMPUTATION OF AREAS

170. In Chapter I we have learned something about the use of a transit. In city and railroad surveying the transit is the favorite instrument, as the needle-compass and the solar compass are too uncertain where precision is required. In regions where land is valuable, especially in the proximity of cities, the transit is now often used for farm surveying.

171. Azimuth. — The true azimuth of a line is the angle which it makes with the geographic (or true) meridian (compare Art. 20).

The azimuth of a line with reference to any given line AB, as a reference line (*e.g.*, some preceding line of a survey), is the angle made by the line with AB (*not* BA), or AB prolonged, the measurement being always around to the right (clockwise motion) from 0° to 360°.

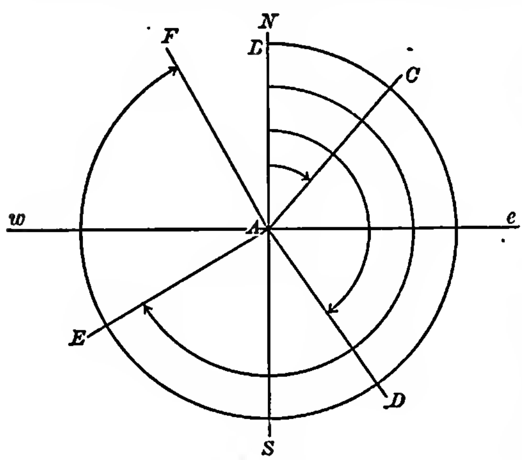


Fig. 57

If the reference line is a meridian, then the bearings of the courses can be at once deduced from their azimuths. For example, suppose AB, the line with reference to which azimuths are to be taken, coincides with the meridian, and the azimuth of AC is 40°; of AD, 145°; of AE, 240°;

* The reader should remember that by "Transit Surveying" is meant surveying with a transit, and that there is no vital difference in principle between "Transit Surveying," so called, and "compass surveying," for example.

of AF, 330°; then it is evident that the bearing of AC is N. 40° E.; AD, S. 35° E.; AE, S. 60° W.; and AF, N. 30° W. Of course azimuth of $Ae = 90°$, of $As = 180°$, of $Aw = 270°$, and of $An = 360°$ or 0°.

172. In this book we shall reckon azimuths in accordance with the definition given in the last article; that is, if the reference line is a meridian, azimuth will be counted from the *north* point,* clockwise. Thus, the azimuth of BC, in figure below, with AB is the angle xBC; the azimuth of CD with AB is the angle yCD, zy being parallel to AB.

The field operation of getting azimuths is given in the next article.

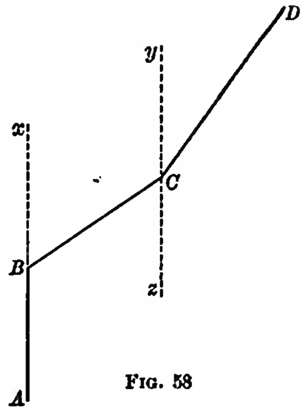


FIG. 58

173. To survey a Farm with the Transit. — Suppose we wish to refer all lines of the field $ABCDEFGA$ (Fig. 59) to the line AB. Set up the transit so that the plummet is directly over the point B (marked by a tack in the top of a stake), clamp the alidade to the limb so that one of the verniers, say vernier A, shall read zero, and sight the point A, then clamp the limb to the spindle, getting the line of sight exactly on the point A by means of the *tangent screw belonging to the lower limb.* Revolve the telescope on its H (horizontal) axis, and it will then point in the direction Bp, the prolongation of AB. Loosen the alidade and sight C, or some well-defined point on the next course BC, bisecting the point exactly by means of the *alidade tangent screw;* † the reading of the vernier, in this case 82° 33′, gives the angle pBC, the azimuth of BC with AB. After reading this angle and recording it, loosen the limb, take up the transit and set it over C (as the party moves along, the courses should be carefully measured with a chain or tape and their lengths recorded); revolve the telescope back on its H-axis (if this has not already been done), sight B, and clamp the limb, using the lower tangent screw to bisect the point (remember that now both the alidade and limb are clamped); then revolve the telescope about its H-axis, making it

* Astronomers and geodesists reckon azimuth around from the *south* point, clockwise. Professor Johnson, in his work on Surveying already mentioned, thus reckons it, while Professor Raymond finds it more convenient to reckon it from the *north* point.

† The beginner is cautioned against the common mistake of turning the wrong tangent screw.

point towards q; loosen the alidade and sight the next point D; the reading of the vernier, 174° 36′, will now give the azimuth of CD *with* AB, or the angle xCD. Notice that after moving the instrument to C and sighting B, the (horizontal) limb has now its zero-point in the direction of xy, or pA.* Also notice that before we loosen the alidade the reading of the vernier is still the angle $pBC = xCq$, and when, after revolving the telescope and loosening the alidade, we sight D, we add to this angle the angle qCD, that is,

$$xCq + qCD = xCD.$$

Lines drawn through the corners parallel to the initial line AB, such as yx, give the direction of *the zero of the limb at each corner before the alidade is loosened.*

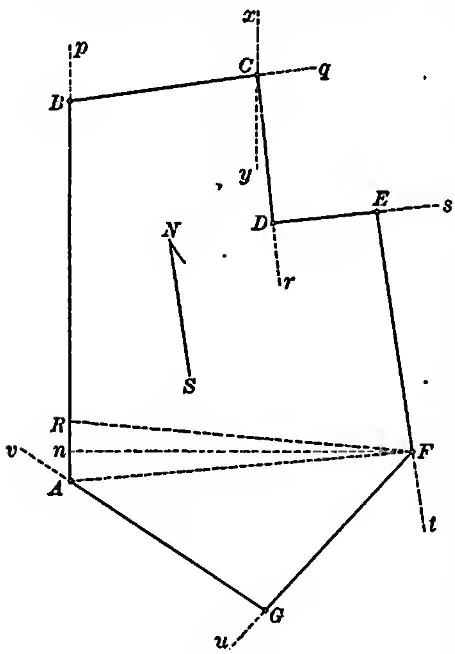


FIG. 59

Next, after having recorded the azimuth of CD, loosen the limb and move the instrument to D, revolve the telescope back on its H-axis, sight C, using lower clamp and tangent screw, revolve the telescope on its H-axis (toward r), loosen alidade and sight E, the reading, 83° 50′, will be the azimuth of DE. Continue thus till A is reached, duly recording all azimuths and distances in the proper columns. It is not necessary to set up the instrument at A, but it should always be done if possible, for it furnishes a strong check on the measurement of the angles. After setting up at A, orienting the transit as at the other stations, and sighting B (where the transit was first set up), the vernier should read 360° or 0°. If it does not, there is some mistake in getting the angles, and if the error is considerable, the lines should be re-run. In order that this last reading shall be 360°, the plummet must be exactly over the point, the rod must in every case be bisected by the line of sight while it is held exactly over the station sighted, and the alidade must not

* Getting it in this position is called *orienting* the instrument.

slip.* In the example here given this test reading, from A to B, was actually 359° 56′, four minutes out.

The magnetic bearing of each line should be taken as a rough check on the reading of the azimuths, even when not needed for use in the deed to the land. Much labor is often saved by thus discovering, before the instrument is moved, an error in reading an azimuth, or possibly an error due to the slipping of the alidade or limb. Using the magnetic bearings, the surveyor mentally calculates the angle between two adjacent courses and compares this with the same angle derived from the azimuths. If they differ much, the error is probably in the azimuth. By this means gross errors in the use of the transit may be detected.

174. In his field book, the surveyor records the stations, distances, magnetic bearings, and azimuths, as given in the first four columns of the form below. On the right-hand page of his field book he will naturally give all data concerning location of corners, offsets, etc.

FORM (a).

Stations	Distances (ft.)	Magnetic Bearings	Azimuths with AB	Bearings with AB as North	Computed Magnetic Bearings†
A	594.9	N. 8° 40′ E.	359°56′ 0	North	N. 8° 13′ E.
B	294	S. 88° 55′ E.	82° 33′	N. 82° 33′ E.	S. 89° 14′ E.
C	232.8	S. 3° W.	174° 36′	S. 5° 24′ E.	S. 2° 49′ W.
D	163	S. 88° E.	83° 50′	N. 83° 50′ E.	S. 87° 57′ E.
E	380	S. 0° 5′ W.	171° 52′	S. 8° 8′ E.	S. 0° 5′ W.
F	337.8	S. 51° 25′ W.	222° 59′	S. 42° 59′ W.	S. 51° 12′ W.
G	362	N. 47° 25′ W.	304° 11′	N. 55° 49′ W.	N. 47° 36′ W.

175. Azimuths changed into Bearings. — To obtain the area by the D. M. D. method, we change azimuths into bearings. It is convenient to get first the bearings of the course, considering AB as a meridian (even though it does not run north and south), as given in column 5, Form (a). This would be sufficient for determining the areas, but, as the magnetic bearings are usually required in all forms of deeds to farms, we change the bearings by the number of degrees

* The clamp screws should be made tight, but not too tight. The beginner is apt to exert too much force in turning the screws.

† Assuming the observed bearing of EF, S. 0° 5′ W., as correct.

representing the angle between AB and the magnetic (or true *) meridian, so that now all the courses have their real bearings with the magnetic (or true) meridian. These new bearings (column 6, Form (*a*)) are called the "computed magnetic bearings." For this purpose, we should get with great care the magnetic bearing of AB and derive the magnetic bearings of the other courses from their *bearings with AB* (column 5). It may, in some cases, be better to assume the observed magnetic bearing of some other course as correct, and derive the others from this, using of course their bearings with AB.

In the example we use for illustration, the observed magnetic bearing of EF (S. 0° 5′ W.) was considered the most reliable, as the needle seemed more or less affected by telephone wires and wire fences at all the other corners, and could not be relied upon.

176. Computation of Areas. — After getting the bearings that we wish to use, the computation of areas is made exactly as in Compass Surveying (see Chapter IV). Far less error is to be expected than in compass work; and as the error may be assumed to be due mainly to the chaining, we here use Rule II (Art. 153) in balancing the latitudes and departures.

In transit surveys, where the angle may be read to within two minutes, a traverse table cannot be used advantageously. Most surveyors will prefer to compute each latitude and departure by logarithms, as was done in this example. Below we give a convenient form for arranging the logarithms (Form (b)). Here a five-place table was used, but in most cases a four-place table will prove sufficiently accurate. The reduction of the area is given in Form (c), page 113.

Form (*b*)

Courses	AB	BC	CD	DE	EF	FG	GA
log sin B	9.15508	9.99996	8.69144	9.99972	7.16270	9.89173	9.86832
log dist.	2.77444	2.46835	2.36698	2.21219	2.57978	2.52866	2.55871
log cos B	9.99552	8.11693	9.99948	8.55354	0.00000	9.79699	9.82885
log D.	1.92952	2.46831	1.05842	2.21191	9.74248	2.42039	2.42703
D.	85.02	293.97	11.44	162.90	0.55	263.26	267.32
log L.	2.76996	0.58528	2.36646	0.76573	2.57978	2.32565	2.38756
L.	588.79	3.85	232.52	5.83	380.0	211.66	244.09

* If a solar attachment is used, the bearings would be referred to the *true* meridian.

FORM (*c*)

Stations	Computed Magnetic Bearings	Dists. (ft.)	Latitude		Departure		Cor.		Balanced		D. M. D.	Areas	
			N. +	S. −	E. +	W. −	L.	D.	L.	D.		+	−
A	N. 8° 13′ E.	594.9	588.70		85.02		33	5	+580.12	+85.07	+85.07	50116.438	
B	S. 89° 14′ E.	204		3.85	203.97		0	18	−3.85	+294.15	+464.29		1787.516
C	S. 2° 49′ W.	232.8		232.52		11.44	14	0	−232.38	−11.44	+747.00		173587.860
D	S. 87° 57′ E.	163		5.83	162.90		0	13	−5.83	+163.03	+898.59		5237.580
E	S. 0° 5′ W.	380		380.00		0.55	23	0	−379.77	−0.55	+1061.07		402062.554
F	S. 51° 12′ W.	337.8		211.66		263.26	13	16	−211.53	−263.10	+797.42		168678.252
G	N. 47° 36′ W.	362	244.09			267.32	15	16	+244.24	−267.16	+267.16	65251.158	
		2364.5	832.88	833.86	541.89	542.57						115367.596	752253.762
				832 88		541.89							115367.596
													2)636886.166
													318443.083 sq. ft.

Error in latitude = 0.98 0.68 = error in D.

Error of closure $= \dfrac{\sqrt{.98^2 + .68^2}}{2364.50}$, or 1 in 1983.

Area = 7.31 acres.

177. By the method just given, let the student compute the area of a lot of which the field notes are as follows:

"DRILL FIELD"

STATIONS	DISTANCES (ch.)	AZIMUTHS WITH *AB*	MAGNETIC BEARINGS*
A	4.41	0	N. 22° 40′ W.
B	24.82	90° 6′	N. 67° 30′ E.
C	4.43	180° 2′	S. 22° 25′ E.
D	3.38	267° 29′	S. 65° 30′ W.
E	2.29	261° 8′	S. 59° W.
F	19.20	271° 40′	S. 69° 40′ W.

178. Interior Angles. — Another way of using the transit in a farm survey is to measure the interior angles, from which the azimuths or bearings with any of the courses may be readily derived. This was done in the following survey:

FIELD NOTES

STATIONS	DISTANCES (ft.)	MAGNETIC BEARINGS	INTERIOR ANGLES
A	289.1	N. 51° 25′ E.	270° 14′
B	776.4		48° 48′
C	402.0		49° 54′
D	426.3		173° 9′
E	298.3		89° 36′
F	246.0	S. 38° 30′ E.	88° 19′

In the above table the interior angle recorded opposite A means that angle $FAB = 270° 14'$, and $ABC = 48° 48'$, etc. It is left as an exercise for the student to compute from the interior angles the azimuths with respect to AB, and the magnetic bearings of all the courses, considering that of AB, N. 51° 25′ E., as correct. Also plot and compute the area.

179. Deflection Angles. — Another way of getting the direction of lines is to measure the deflection angles, a *deflection angle* being the angle which a line of a traverse makes with the prolongation of the line immediately preceding it; if it passes to the right of the

* In getting the "computed magnetic bearings," assume the bearing of AB, N. 22° 40′ W., as correct. The error of closure will be found to be very small.

line prolonged, R. is written after the angle, if to the left, L. This is a convenient method to employ in running a traverse of a highway or railroad.

For example, suppose that a section of an irregular highway from *A* to *G*, Fig. 60, is to be traversed, and that it is found convenient to make stations at *A*, *B*, *C*, *D*, *E*, *F*, and *G*, the exact bounds of the road being obtained by measuring offsets from the traverse line. The instrument is set up at *B*, and, the vernier of the alidade being set at zero, *A* is sighted, then the telescope is revolved on its *H*-axis, and the angle rBC ($=46°$) is obtained in the usual way. It is written 46° L., to indicate that the deflection is to the left. Measure the distances, *AB*, *BC*, etc., as the work progresses, and take offsets at intervals sufficiently close to determine the boundary of the road, if that is required. Move the instrument to *C*, again set the vernier at zero, and as before measure the deflection $sCD = 75° 40'$ R., noting that this time the deflection is to the right. Proceed in this way till the end of the traverse is reached. It is often an advantage to have some of the lines entirely outside the limits of the road, the centre line of which is readily determined by offsets.

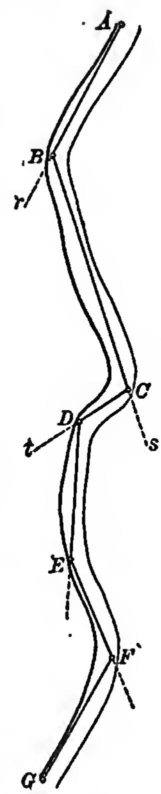


FIG. 60

180. The length of each course may be recorded separately, but in work where deflection angles are used, the lines are usually measured continuously from the beginning, and the stations are indicated, not by letters, but by numerals which indicate their distance from some initial point; thus:

"0" = the initial station.

"1" = station 100 ft. from the initial point.

"2" = station 200 ft. from the initial point.

"5 + 40" = station 540 ft. from the initial point.

This method of naming the stations has the advantage of showing at a glance the distance that has been covered.

Following we give, as an illustration, notes actually taken in traversing a road:

Notes. — Road to Green's View

Stations (Total Distances)	Deflection Angles	Remarks
Δ 0	58° 15′ R.	Δ "0" is also Δ "0" of preceding traverse (*abcd* . . .), and the angle 58° 15′ R. is the deflection with *ba* of that traverse.
Δ 1 + 69	42° 50′ L.	Δ "1 + 69" = Hub east side of road, 2 ft. from fence post, and on line with K–S's south fence.
Δ 10 + 87	11° 45′ R.	Δ "10 + 87" = Hub at forks of road, Milhado's corner.
Δ 14 + 36	46° 43′ R.	
Δ 19 + 49	60° 12′ L.	Δ "19 + 49" = Hub near old log at forks of roads to Green's View and Hodgson's Spring.
Δ 22 + 23	30° 27′ L.	
Δ 29 + 50	9° 25′ L.	Δ "29 + 50" = Hub on right side of road, at fork of Beckwith Point road. Deflection of B. P. road = 38° 39′ R.
Δ 32 + 54	10° 7′ L.	
Δ 37 + 93	13° 12′ L.	
Δ 44 + 05	2° 48′ L.	
Δ 46 + 72	34° 52′ R.	
Δ 50 + 98	——	Δ "50 + 98," Hub 26 ft. from road, right of Green's View on brow of point.

Some such form as this is usually employed in running out highways and railroads. It is beyond the scope of this work to describe the methods of laying out curves, though the field operations are very simple.

EXAMPLES

1. Survey a field * or farm with a transit, recording the azimuths of the courses and their magnetic bearings as a check, plot and compute its area by the method of Art. 176.

2. Let another party, or the same party, survey the same field, finding the *interior angles*, and plot and compute the area, comparing the results with those found in Example 1.

3. Lay off, with the transit and a chain or tape, a square † to contain 108,900 sq. ft.

4. Run a traverse out one road, returning by another route to the starting point, by means of deflection angles. Test the accuracy of the work by plotting.

5. By the method of Art. 143, establish a true meridian line, and determine the declination of the needle at the point of observation.

* The student should have as much practice in field work as possible, and he can thus make his own examples, and supplement the small list given here.

† The beginner will be surprised to find that it requires great care to lay off a *square*.

Plot, determine the error of closure, and compute the areas in the following transit surveys.

6

Stations	Azimuths with SN, a True Meridian	Distances (ft.)
A	267° 22′	742
B	186° 52′	427.7
C	174° 45′	271.2
D	172° 28′	266.3
E	41° 42′	722.3
F	29° 12′	519.2

7

Stations	Azimuths with AB	Magnetic Bearings	Distances (ft.)
A	0	N. 39° 15′ W.	408
B	91° 13′	N. 51° 45′ E.	463
C	173° 55′	S. 45° 15′ E.	415.1
D	257° 39′	S. 38° 45′ W.	208.4
E	188° 31′	S. 30° 45′ E.	165.1
F	280° 8′	S. 61° W.	334.9
G	17° 8′	N. 22° 15′ W.	171.5

Ans. 6.11 A.

8

Station to Station	Azimuths with True Meridian	Distances (ch.)
1 to 2	335° 50′	51.90
2 to 3	91° 42′	20.60
3 to 4	127° 46′	16.50
4 to 5	159° 47′.	19.80
5 to 1	227°	26.40

9

Stations	Azimuths with AB	Distances (ft.)
A	0	310
B	101° 34′	225.6
C	127° 37′	290.7
D	180° 55′	221.8
E	267° 25′	345.4
F	330° 8′	205.5

II. LAYING OUT AND DIVIDING LAND

181. To lay out a lot of given area in the shape of a triangle, the base being given.

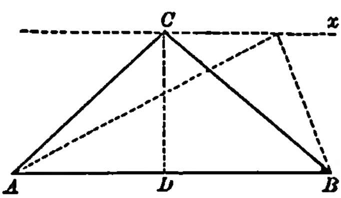


Fig. 61

Let $S =$ given area,

$AB = b$, given base.

Then the altitude is

$$h = CD = \frac{2S}{b},$$

and evidently the vertex may lie anywhere in a line Cx, parallel to AB, at the distance h from it.

182. To lay off a lot of given area, in shape of a triangle, one side and an adjacent angle being given.

Here $AC = c$, angle $BAC = A$ are given.

Then $h = c \sin A$, and the base, $b = \dfrac{2S}{c \sin A}$.

Hence lay off $AB = \dfrac{2S}{c \sin A}$ and ABC will be the required triangle.

183. To lay out a lot of given area in shape of an equilateral triangle.

Let $x =$ the side of the triangle.

Then $S = \dfrac{x^2}{4}\sqrt{3}$ (see Table XII)

and $x^2 = \dfrac{4S}{\sqrt{3}}$,

from which we find x, and the construction of the triangle is easy.

If the lot is to be in the shape of a square, $x = \sqrt{S}$. In both cases, if S is given in acres, it must first be reduced to square chains, or some convenient unit.

184. To lay off a rectangle of given area, one side, a, being given.

Here the side perpendicular to the given side is $b = \dfrac{S}{a}$, and the construction follows.

For a parallelogram of given area and base, we have $h = \dfrac{S}{b}$.

At the distance h from the base draw a line parallel to the base. Lines drawn parallel to each other from the extremities of the base intersecting this parallel line determine the parallelogram, there being an indefinite number of solutions.

185. To lay out a lot of given area in the form of a regular polygon of any number of sides.

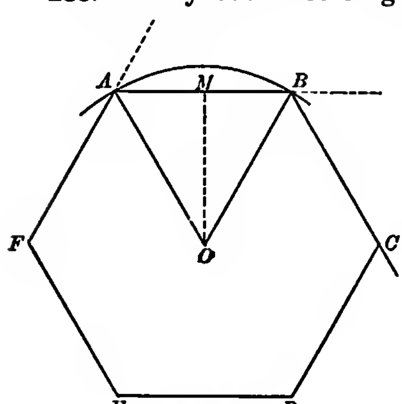


Fig. 62

Given $S =$ area, $n =$ number of sides.

Let $x =$ length of a side, as AB in Fig. 62, and $y = OA =$ the radius of the circumscribed circle.

Then $n \times OM \times AM = S$.

Now

$$AM = \frac{x}{2},\quad OM = \frac{x}{2}\cot\frac{180^\circ}{n},$$

for angle $AOB = \dfrac{360^\circ}{n}$.

Therefore $$n\frac{x^2}{4}\cot\frac{180°}{n} = S,$$

whence x is derived.

Again $$y = \frac{x}{2}\operatorname{cosec}\frac{180°}{n}.$$

Having found in this way the length of a side, stake out $AB = x$, set the transit over B, make the deflection angle $xBC = \frac{360°}{n}$, and lay off $BC = x$.

Move the instrument to C, again deflect by an angle equal to $\frac{360°}{n}$, and lay off $CD = x$. Continue thus until A is reached again.

If the field is small and all the corners visible from the centre, a better method is to find the centre of the circumscribed circle (if the position of one side, say AB, is fixed, let the student show how the centre may be determined), at the required distance, y, from A and B; then set up the instrument over the centre, measure the angles BOC, COD, etc. $= \frac{360°}{n}$, and lay off on the lines thus determined the distances $OC = OD = OE$, etc. $= y$.

If the problem is to lay off a circle of given area, the radius is determined by the equation $S = \pi x^2$. The circumference can be laid off by the method of this article. Take n as large as is convenient, thus establishing as many points as possible, all of which will lie on the circle of radius x.

186. To lay out a lot of given area in the form of an ellipse, the greater and lesser diameters to be in a given ratio $m : n$.

Let S=area, $2\,mx$=greater diameter, $2\,nx$ = lesser diameter.

Now the area of an ellipse is πab, where a and b represent the semi-diameters (Table XII).

Hence $\pi mnx^2 = S$, $\therefore x = \sqrt{S \div \pi mn}$, and thence mx and nx.

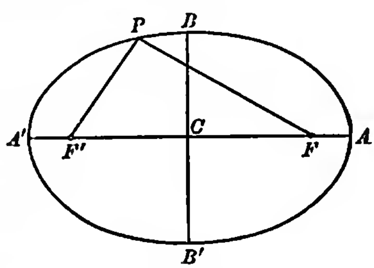


FIG. 63

Construction. — A small ellipse can be conveniently laid off as follows:

Suppose its greater diameter $= 2\,a$, its lesser diameter $= 2\,b$.

Measure $AA' = 2\,a$, and from its centre C lay off $CF = CF' = \sqrt{a^2 - b^2}$. Fix the ends of a chain or wire (some material sufficiently flexible, but not easily stretched) of length $2\,a$ at F and F', and with

a continuous motion of a marking pin P keep the wire taut; the pin will trace out the ellipse. An ellipse can be traced on paper in this way, but care must be taken to prevent slipping or the stretching of the guiding string.

187. To divide a given triangle into two parts in the ratio of $m : n$ by a line parallel to one side.

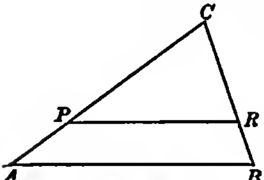


Fig. 64

Let ABC be the given triangle.

Denote the sides opposite A, B, C by a, b, c respectively. The problem is to draw PR parallel to AB, so that area $ABRP : PRC = n : m$. Let $CP = x$, $PR = y$. Then, since areas of similar plane figures are to each other as the squares of homologous sides, we have

$$\text{area } ABC : \text{area } PRC = b^2 : x^2,$$

but

$$\text{area } ABC : \text{area } PRC = m + n : m.$$

$$\therefore\ b^2 : x^2 = m + n : m.$$

$$\therefore\ x^2 = b^2 \frac{m}{m+n}, \text{ or } x = b\sqrt{\frac{m}{m+n}}.$$

Hence, measure $CP = x$, set up the instrument at P, lay off the angle $CPR = A$, and range out the line PR. As a check on the work, measure PR, and compare the result with its length determined by the proportion: $PR : AB = CP : CA$, or $y : c = x : b$.

If the triangle is to be divided into equal parts, $x = \frac{1}{2} b \sqrt{2}$ and $y = \frac{1}{2} c\sqrt{2}$.

188. To divide a given triangle into two parts in the ratio of $m:n$ by a line from a vertex to the opposite side.

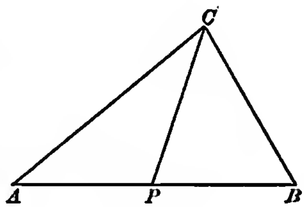


Fig. 65

To draw CP, so that $ACP : PCB = m : n$.

Let $AP = x$. Then, since the triangles ACP and ACB have the same altitude, they are to each other as their bases,

$$ACP : ACB = AP : AB = x : c,$$

but

$$ACP : ACB = m : m + n.$$

$$\therefore\ x : c = m : m + n, \text{ or } x = \frac{mc}{m+n}.$$

If

$$m = n,\ x = \frac{c}{2}.$$

189. To divide a given quadrilateral into two parts having a given ratio, by a line extending from a given point in one of the sides.

Suppose it is required to divide the quadrilateral $ABCD$ into two parts, S, S', so that $S:S'=m:n$, by a line drawn from P, a point in DA.

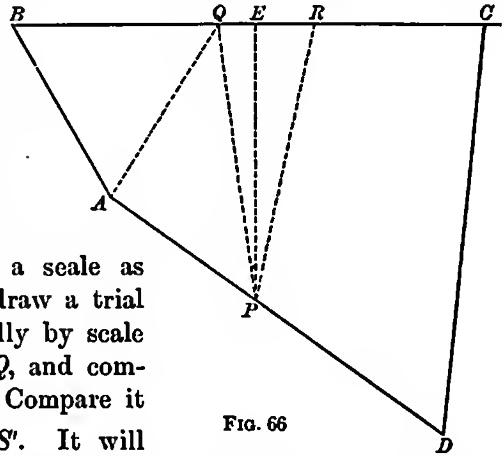


Fig. 66

Make a plot of the quadrilateral on as large a scale as practicable. Through P draw a trial line PQ. Measure carefully by scale the lines PQ, BQ, and AQ, and compute the area of $ABQP$. Compare it with the value of $S=\frac{m}{n}S'$. It will probably differ from S considerably; call this difference x. Now draw a perpendicular $p=PE$, from P to BC, and get its length by the scale. Then the base of a triangle with vertex at P, which is to be added to or subtracted from $ABQP$, is $=\frac{2x}{p}$. Lay off from Q on BC this distance $QR=\frac{2x}{p}$, and $ABRP$ will be the required area. In any case BR and PR should be ranged out on the ground and measured. If the area is not exact enough, another trial may make it all right.

190. Given a Polygon, to divide it into Two Parts having a Given Ratio. — This is a problem of which the preceding is a special case. It is perfectly general, and the method may be readily applied where an estate, or a single field, given by the bearings and distances of the courses, is to be divided into two parts having a given ratio, or where a given area is to be cut off. An example will make the process clear.

For illustration, take "Elliott Park," a plot of which is given on page 110, Fig. 59, and the computation of the area on page 113; and suppose it is required to cut off from the south end of the park, by a line drawn from F, two acres, or 87,120 sq. ft.

We first calculate the area of the triangle FGA (see Case I, Art. 160), and find it to be 61,640 sq. ft. Subtracting this from 87,120, we get 25,480 sq. ft. Now, having carefully plotted the field (Fig. 59), we measure by our scale the perpendicular Fn, dropped from F

to AB, finding it to be 532 ft. Dividing double the additional area (2×25480) required by 532 we get 95.8 for the distance AR, and $ARFGA$ is the required area. Test this both on the plot and in the field by finding the bearing and length of the course FR.

The above problems in laying out and dividing land are merely suggestive. The surveyor's knowledge of geometry and trigonometry, as well as his personal experience in the field, will suggest many other similar ones.

III. STADIA SURVEYING*

191. The geometrical theorem that in similar triangles homologous sides are proportional furnishes the fundamental principle upon which stadia measurements are based.

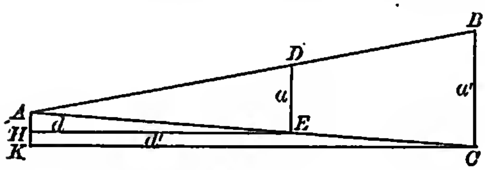


Fig. 67

Suppose DE ($=a$) and BC ($=a'$) to be parallel, and let their distances from the vertex A be d and d' respectively; then $a' : a = d' : d$, that is, the lengths of parallel lines subtending an angle are proportional to their distances from the vertex; for example, if $a' = 2a$, then $d' = 2d$.

192. Stadia Wires. — The practical application of this principle is accomplished by having in the reticule of the telescope two horizontal wires (see Art. 62). The lengths intercepted by these parallel wires on a vertical rod held in front of the instrument are, with a slight modification, proportional to the distances of the rod from the instrument. The theory of stadia measurements, which we shall presently establish, will show what this modification is. These wires may be fitted to any telescope, but are especially useful in the telescope of the transit and the alidade of the plane-table.

193. Horizontal Sights. — In Fig. 68, LL' is supposed to be the objective lens, of which E_1 and E_2 are the "principal points," † and F is the principal focus, or the position of the image for an object

* In preparing this account of Stadia Surveying, the author has consulted articles by George J. Specht and Arthur Winslow, both published by Messrs. D. Van Nostrand Co.

† For simplicity these points are usually made to coincide at the centre of the lens, O, which, while not rigidly accurate, makes no appreciable difference in the results obtained.

an infinite distance away, and C is the centre of the telescope over the plummet.

Let $AB = s =$ portion of rod intercepted between the stadia wires, and $A'B' = i =$ the image of AB at the reticule.

Let $E_1F = f$, the principal focal length,

$$\left.\begin{aligned} E_1I &= f_1 \\ E_2P &= f_2 \end{aligned}\right\} \text{conjugate foci.}$$

$E_2C = c$, distance from objective to centre of the instrument.

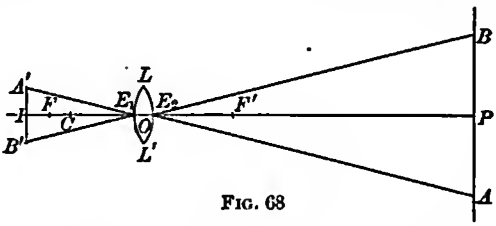


Fig. 68

From similar triangles, AE_2B, $A'E_1B'$, we have

$$E_2P : E_1I = AB : A'B', \text{ or}$$

$$f_2 : f_1 = s : i. \tag{1}$$

From a law of lenses, $\dfrac{1}{f_1} + \dfrac{1}{f_2} = \dfrac{1}{f}$. (2)

Eliminating f_1 between (1) and (2), we have

$$f_2 = \frac{f}{i}s + f, \tag{3}$$

and putting $k = \dfrac{f}{i}$,

$$d = CP = ks + f + c. \tag{4}$$

We see from this that $\dfrac{f}{i}s$ is the distance from F', a point in front of the objective at a distance from it equal to the focal length. As we want the distance from the centre of the instrument, we must add to this the constant, $f + c$.

194. It is the necessity of adding this constant to the reading from the stadia rod that has prejudiced many surveyors against stadia work. To obviate this difficulty, some have the rod arbi-

trarily graduated, so that, at the distance of an average sight, say 300 ft., the same number of units of graduation are intercepted on the rod as units of length are contained in the distance. It should be remembered, however, that the distance read is strictly correct only for the 300 ft.

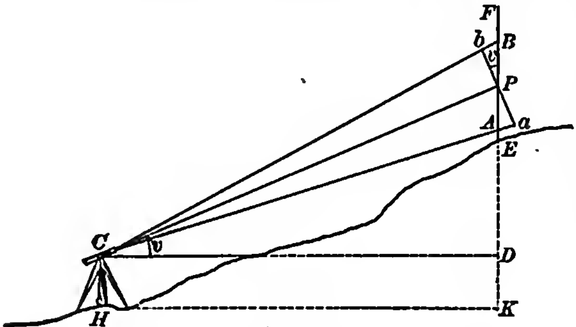


Fig. 69

The stadia wires are made either fixed or adjustable. If fixed, and this is usually the better plan, it is convenient to space them so that $k = 100$; then, if the rod reading is 2 ft., the distance is 200 ft. plus the constant $f + c$, or, if the rod reading is 3.4, the distance is 340 ft. plus $f + c$.

195. This constant, which in ordinary transits varies from 10 to 16 in., should be determined for the instrument used, as follows: Measure with a rule the distance from the objective to the centre of the instrument, which gives c. Focus the telescope on a very distant object, preferably the moon or a star, and measure the distance from the objective to the reticule, which will be f. When an instrument with fixed stadia wires is purchased, the maker will give the value of this constant and also k.

In the 11-in. telescopes of Gurley, $c = 5\frac{3}{10}''$ and $f = 8''$, $f + c = 13\frac{3}{10}''$.

196. The value of k may be determined as follows:

Set up the instrument and measure off in front of the plummet a distance $= f + c$. Then from this point, which we will call A, measure some convenient distance, as 400 ft., to a point B in the line of sight. Hold the rod vertically at B and read the space intercepted by the wires, calling this s'; then

$$400 + f + c = ks' + f + c,$$

$$\therefore\ ks' = 400,$$

or $$k = \frac{400}{s'}, \text{ and } k \text{ is known.}$$

If $$s' = 4,\ k = 100.$$

Equation (4), Art. 193, gives the horizontal distance on level or nearly level ground. As most lines are run on ground that is not level, we need another formula.

FORMULÆ FOR INCLINED SIGHTS

197. In going up or down a hill, if the rod is held perpendicular to the line of sight, Formula (4) will give the linear distance to the rod. But it is inconvenient to hold the rod in this inclined position, and besides, this linear distance would have to be reduced to horizontal measurement. The formula that we shall now deduce gives the horizontal distance when the stadia rod is held in a vertical position.

Let C, Fig. 69, be the centre of the telescope, over the point H, EF the stadia rod held vertically at the point E, CP the line of sight, and AB the part intercepted on the stadia rod.

Draw through P a line ab perpendicular to CP.

Let $AB = s$, $ab = s'$, angle $PCD = v = bPB = aPA$. Now the angle ACB is so small that no appreciable error will be made if we consider the angles BbP and AaP as right angles. Assuming this, we have

$$aP = AP \cos v, \quad Pb = PB \cos v.$$

$$\therefore\ ab = AB \cos v, \quad \text{or} \quad s' = s \cos v.$$

Now, by Formula (4), putting s' for s,

$$CP = ks' + (f + c), \tag{5}$$

$$\therefore\ CP = ks \cos v + f + c; \tag{6}$$

and

$$CD = d = CP \cos v,$$

or

$$d = ks \cos^2 v + (f + c) \cos v, \tag{7}$$

which is the required formula.

We also have for the elevation of the point E above H (provided that P is at a distance from the ground at E equal to the height of the instrument),

$$PD = h = CP \sin v,$$

hence

$$h = ks \cos v \sin v + (f + c) \sin v,$$

or

$$h = \tfrac{1}{2} ks \sin 2v + (f + c) \sin v. \tag{8}$$

Hence, Formula (7) gives the distance, and (8) the elevation, reading v on the vertical arc of the instrument, and s on the rod, k, f, and c being constant for the instrument used.

198. Stadia Tables. — To save the labor of solving Equations (7) and (8) every time a reading is taken, tables are constructed giving distances and heights * for observed values of v and s. For an illustration, see Table XVI, in which d and h are computed from the formula for a stadia reading of 100 ft. (or metres), with angles up to 30°.

The use of this table involves one multiplication and one addition. For instance, if we want the horizontal distance (h) and difference of elevation (d) corresponding to $s = 3.42$, $v = 6° 30'$, we get the proper values from the table, page 156, in the column headed 6°, opposite 30′. These values must be multiplied by 3.42, and to the results must be added the corrections, $(c+f) \cos v$ and $(c+f) \sin v$, respectively, also given in the same column opposite the letter c (say 1.00), thus,

$$d = 98.72 \times 3.42 + 0.99 = 338.61,$$
$$h = 11.25 \times 3.42 + 0.11 = 38.58.$$

Three values of c are given, to enable the surveyor to use a value which nearly corresponds to the particular telescope that he is using.

It is not necessary to use the table for getting the horizontal distance d for angles of elevation or depression less than about 4°, and if an error of 1 in 100 is permissible, then the reduction need not be used under 6°. (In such cases Formula (4) gives the distance.) If $c+f$ be neglected, as well as v, these two errors tend to compensate for each other.

In obtaining the difference of elevation h, the term in $c+f$ may be omitted for angles less than 6°, if errors of 0.1 ft. are unimportant.

199. The chief advantage of stadia work lies in the fact that it saves the labor of chaining. This advantage is especially felt in rough, rolling country. As to its accuracy, the combined experience of many surveyors seems to show that it is as accurate on fairly level ground as ordinarily good chaining, more accurate than unusually good chaining on rolling ground, and much more accurate on any ground than ordinary chaining. Care must be taken to avoid gross errors. The most common errors appear to be compensating rather than cumulative, as is shown in the example given in the following article.†

* A particular form of the slide-rule is made for reading with ease and rapidity the distance and heights.

† Taken, by permission, from Professor J. B. Johnson's "Theory and Practice of Surveying."

200. "A good example of the use of the transit and stadia method in running levels in city topographic surveys is found in the recent topographic survey of St. Louis. In this survey a transit and stadia

RESULTS OF LEVELING BY THE STADIA METHOD

Stations	Azimuth Errors	Accumulated Errors in Elevation (ft.)	Distances in Miles from Starting-Point	Errors in Horizontal Measurement	Error of Closure in Elevation between Check-points (ft.)
	° ′ ″				
2547	0 1 20	+ 0.42	2.0	+ 1 : 387	0.42
2803	0 50	+ 0.46	4.1	+ 1 : 619	0.04
2777	2 20	+ 0.17	6.2	+ 1 : 1177	0.29
1332	2 00	+ 0.09	7.8	+ 1 : 1149	0.08
1393	2 00	+ 0.50	9.2	+ 1 : 987	0.41
774	3 33	+ 0.52	10.9	+ 1 : 1000	0.02
400	8 13	+ 0.09	12.3	+ 1 : 1084	0.43
389	7 06	+ 0.08	14.6	+ 1 : 1203	0.01
1839	9 32	+ 0.25	16.3	+ 1 : 1025	0.17
1871	9 52	− 0.01	18.4	+ 1 : 965	0.26
2008	10 42	+ 0.14	20.5	+ 1 : 836	0.15
2067	11 42	+ 0.37	22.4	+ 1 : 877	0.23
41	12 12	+ 0.39	23.8	+ 1 : 961	0.02
2292	11 42	+ 0.77	25.2	+ 1 : 1063	0.38
2304	10 42	+ 1.37	27.0	+ 1 : 1139	0.60
1699	10 42	+ 1.00	28.9	+ 1 : 1484	0.37
566	9 40	+ 1.23	30.3	+ 1 : 1644	0.23
1500	9 05	+ 1.03	31.8	+ 1 : 1724	0.20
1488	10 00	+ 0.68	33.5	+ 1 : 2267	0.35
937	12 35	+ 0.94	34.9	+ 1 : 3291	0.26
958	9 18	+ 0.98	36.2	+ 1 : 3945	0.04
1115	9 30	+ 0.64	37.9	+ 1 : 5174	0.34
2476	8 20	+ 0.36	39.8	+ 1 : 6420	0.28
124	8 20	+ 0.64	40.4	+ 1 : 6332	0.28

line was run over 40 mi. long. At twenty-four points along this circuit the line checked on triangulation points and precise-level bench-marks, with the results shown in the table above.

"The average length of the lines between check-points was 1.7 mi. and the average error for this distance was 0.24 of a foot, or 0.18 of a foot per mile of line.

"It should be noted that while the total accumulated error in elevation for the entire 40 mi. was but 0.64 of a foot, at a point on the line distant 20 mi. from the beginning the error in elevation was

zero, while in 7 mi. more it was over twice the error at the end of the circuit, thus emphasizing the fact that the errors in such work tend to compensate."

201. Stadia Rods. — The ordinary leveling-rod, with target or self-reading, may be used, but it is generally more convenient to have a special rod constructed for the purpose. Many designs are in use, the main object being to get a form which may be easily read at a distance. Such a self-reading rod is described in Art. 98, and represented in Fig. 22.

202. To any one who has had experience in handling a transit, the field operations in stadia work will present no special difficulties. The surveyor must be careful not to read the space on the rod intercepted between one stadia wire and the *middle* horizontal wire instead of the space (which is twice as great) between the two stadia wires. In the next chapter attention will be called to the use of the stadia in topographical work. In getting elevations, remember that the middle wire should (to be exact) cut the rod at a distance above the ground equal to the height of the instrument. For the best results a telescope of good defining power is desirable, and the instrument must be in nearly perfect adjustment.

203. Field Notes. — The form of the field notes varies according to the object of the survey.

When a traverse is run and at the same time the profile of the traverse is desired, the form for field notes and reduction given below is suggested. These notes were taken in running a line for a highway.

As the vertical angle v was small on this part of the line, the example selected serves to show that, if the distance (d) alone is desired, the reduction formulæ for inclined sights may be disregarded for small values of v, as has already been stated. Here the stadia station * G is itself used as a B. M., and is 100 ft. above a certain datum plane (see Art. 218). The last reading from ⊡ G is on ⊡ H, which is used as a T. P.,† its elevation being found to be 120. The transit is then moved to H. The numbers given in the h column are now the elevations above or below ⊡ H, and are to be added (algebraically) to 120 to obtain the final elevations given in the 7th column. Here ⊡ H is evidently on the line HI, and is used as an intermediate station to prolong the line, and incidentally as a T. P. The next station, I, is also used as a T. P.

* Denoted by ⊡ G.

† Turning-point; see Art. 217.

In the form, ⊡ *H* and ⊡ *I* could have been written in the line just above where they are placed; but the present arrangement avoids confusion. If the work is to be continued, the last reading should be on a B. M.

Note. — If ⊡ *H* was used simply as a T. P., and was not necessary for prolonging the line, time could be saved by occupying ⊡ *I*, on moving from ⊡ *G*, and taking back-sights on *H* and the points between *H* and *I*; but in considering the sign of *v*, it must be remembered that the sight has been reversed, and this must be indicated in the field book.

In the reduction below, the *c* of the table is supposed to have the value 1.

Form for Stadia Notes

Stations	Azimuths*	*v*	*s*	*d*	*h*	Elevations	Total Distances
⊡ *G*	90°				0.0	100.0	0.00
		+ 2° 20′	0.83	83.86	+ 3.4	103.4	83.86
		+ 1° 45′	1.50	150.85	+ 4.6	104.6	150.85
		+ 2° 12′	2.33	233.65	+ 8.9	108.9	233.65
		+ 2° 56′	3.06	306.20	+ 15.7	115.7	306.20
		+ 2° 57′	3.90	389.99	+ 20.0	120.0	389.99
⊡ *H*	90°			0.00		120.0	T. P.
		+ 0° 30′	0.67	68.00	+ 0.6	120.6	457.99
		+ 0° 49′	1.20	120.99	+ 1.7	121.7	510.98
		− 0° 28′	1.84	185.00	− 1.5	118.5	574.90
⊡ *I*	116° 52′			0.00		118.5	T. P.
		− 0° 40′	0.98	98.99	− 1.1	117.4	673.98
		− 1° 45′	2.87	287.74	− 8.8	109.7	862.73
		− 0° 2′	4.96	497.00	− 0.3	118.2	1071.99
B. M.		− 0° 8′	7.30		− 1.7	116.8	B. M.

IV. PUBLIC LANDS OF THE UNITED STATES

204. We cannot in this brief treatise enter into the details of the survey of the public lands of the United States. The short discussion which we give is taken mainly from the "Manual of Surveying Instructions for the Survey of the Public Lands of the United States and Private Land Claims," † to which volume the student is referred. Brief accounts of these Government Surveys will be found in the works on surveying mentioned.

* Here ⊡ *G*, used as a B. M. or T. P., is 100′ above datum plane.
Azimuths are taken with reference to *FG*, a line established on the previous day.

† Published under the direction of the General Land Office, Washington, D.C.

205. The present system of survey of the public lands was inaugurated by a committee appointed by the Continental Congress, of which Thomas Jefferson was the chairman. The first public surveys were made under an ordinance passed in 1785, which provided for townships 6 mi. square, containing 36 sections of 1 mi. square, while a later Act of Congress directed that the sections be divided into quarter sections.

These "rectangular" divisions were referred to certain well-established lines, — the one a *true meridian*, the other an *east and west line*, called the *base line*.

206. The present law requires that in general the public lands of the United States "shall be divided by north and south lines run according to the true meridian, and by others crossing them at right angles so as to form townships 6 mi. square," and that the corners of the townships thus surveyed "must be marked with progressive numbers from the beginning." It also provides that the townships shall be subdivided into 36 sections, each of which shall contain 640 acres, as nearly as may be, by a system of two sets of parallel lines, one governed by true meridians, and the other by parallels of latitude, the latter intersecting the former at intervals of a mile.

These 36 sections are numbered, commencing with number *one* at the northeast angle of the township, and proceeding west to number 6, thence proceeding east to number 12, and so on, alternately, to number 36 in the southeast angle.

207. Owing to the convergence of meridians, of course the townships could not be exactly 6 mi. square, but would be of a trapezoidal form. To prevent this error from accumulating, standard parallels are established every 24 mi. north and south of the *base line*, and auxiliary meridians at intervals of every 24 mi. east and west of the *principal meridian*, thus confining the errors resulting from convergence of meridians and inaccuracies of measurement within comparatively small areas.

The above is a general outline of the excellent system adopted by our government. Partly for the sake of emphasizing what has already been said in this book in regard to accuracy in chaining, etc., the following articles contain a few of the many instructions given to the United States surveyors.

208. Instruments. — The surveys of the public lands of the United States, embracing the establishment of base lines, principal meridians,

standard parallels, meander lines, and the subdivisions of townships, will be made with instruments provided with the accessories necessary to determine a direction with reference to the true meridian, independently of the magnetic needle.

Burt's improved solar compass, or a transit of improved construction, with or without solar attachment, will be used in *all* cases. When a transit *without* solar attachment is employed, *Polaris observations* and the *retracements* necessary to execute the work in accordance with existing law and the requirements of these instructions will be insisted upon.

Deputies using instruments with solar apparatus will be required to make observations on the star Polaris at the beginning of every survey, and *whenever necessary to test the accuracy of the solar apparatus.*

The township and subdivision lines will usually be measured by a two-pole chain 33 ft. in length, consisting of 50 links (each = 7.92 in.). On uniform and level ground, however, the four-pole chain may be used. The measurements will, however, always be expressed in terms of the four-pole chain of 100 links. The chain in use must be compared and adjusted with a standard chain each working day.

209. Leveling the Chain and plumbing the Pins. — The length of every surveyed line will be ascertained by precise horizontal measurement, as nearly approximating to an air-line as is possible in practice on the earth's surface. This all-important object can be attained only by a rigid adherence to the three following observances:

First. — Ever keeping the chain drawn to its utmost degree of tension on even ground.

Second. — On uneven ground, keeping the chain not only stretched as aforesaid, but *leveled.* And when ascending and descending steep ground, hills, or mountains, the chain will have to be *shortened* to one-half or one-fourth its length (and sometimes more), in order accurately to obtain the true horizontal measure.

Third. — The careful plumbing of the tally pins, so as to attain precisely *the spot* where they should be stuck. The more uneven the surface, the greater the caution needed to set the pins.

210. Marking Lines. — All lines on which the legal corner boundaries are to be established will be marked after this method; viz., those trees which may be intersected by the line will have two chops

or notches cut on the sides facing the line, without any other marks whatever. These are called "*sight trees*" or "*line trees*." A sufficient number of other trees standing within 50 links of the line, on either side of it, will be *blazed* on two sides diagonally or quartering toward the line, in order to render the line conspicuous, and readily to be traced, the blazes to be opposite each other, coinciding in direction with the line where the trees stand very near to it, and to approach nearer each other toward the line, the farther the line passes from the blazed trees.

These instructions state, moreover, that the required blazes will be made on any tree not smaller than 2 in. in diameter, and that bushes on or near the line should be bent at right angles with the line at about the usual height of *blazes*. Many other details are specified in regard to the careful execution of the work and its permanence, especially with respect to the establishment of durable monuments to mark the corners.

CHAPTER VI

LEVELING

211. Leveling is the art of determining the relative position of points from the centre of the earth. A *line* is on a *true level*, when every point of it is equally distant from the centre of the earth, and a *surface* is a *true level* surface when all points on it are equally distant from the centre of the earth. A straight line tangent to a line of *true level* is sometimes called a *line of apparent level*. It is this latter line that is determined by the line of collimation of the telescope of a leveling instrument.

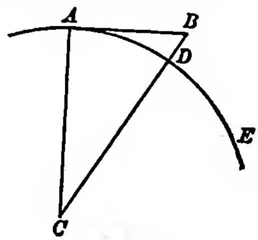


FIG. 70

212. Thus (Fig. 70) if C is the centre of the earth, and ADE a line of true level, AB is the line of apparent level. The difference between the apparent and true level of the points A and D, is BD. This difference, due to the curvature of the earth, is computed as follows:

From geometry, we have

$$\overline{AB}^2 = BD(BD + 2\,DC).$$

Now for practical purposes, AD does not differ sensibly from AB, and BD is so small in comparison with $2\,DC$ that it may be neglected, and the formula becomes

$$\overline{AD}^2 = BD \times 2\,DC,$$

or

$$BD = \frac{\overline{AD}^2}{2\,DC}; \tag{1}$$

that is, the correction for curvature *is equal to the square of the distance divided by the diameter of the earth.*

From Formula (1), the curvature in inches or feet may be computed for any distance. Tables of curvature are thus computed.

If $AD = 1$ mi., $BD = 8.001$ in., or two-thirds of a foot, very nearly; and for any other distance d, *in miles*, we have

$$1^2 : d^2 = \tfrac{2}{3} \text{ of a foot} : x \text{ feet}.$$

$$\therefore\ x, \text{ in feet}, = \tfrac{2}{3} d^2;$$

that is, the following rule gives, approximately, the curvature in feet: *The correction for curvature, in feet, is equal to two-thirds of the square of the distance in miles.*

Refraction acts in a direction opposite to curvature, tending to lessen the effect of the latter.

The instruments used in leveling are described in Chapter I.

213. We shall consider leveling under three heads:

FIRST. — *Differential leveling*, which consists in determining the difference of level between two given points.

SECOND. — *Profile leveling*, which is the operation of obtaining a section or profile along a given line, as a railroad for example.

THIRD. — *Topographical leveling*, which is equivalent to getting the profiles of many different lines, for the purpose of obtaining the elevations and depressions of the ground over a more or less extended area.

DIFFERENTIAL LEVELING

214. To determine the difference of level between two points, A and B, visible from each other, set up the level* at a point about the same distance from A and B, but not necessarily on a line between them, and having leveled the instrument, sight a rod held on A and then on B; the difference of the two readings is the difference of elevation of A and B. After turning the telescope on A, and again after turning it on B, see that the bubble remains in the centre of its tube. This point must not be neglected in using any level. For short distances the corrections for refraction and curvature are small, and are often disregarded. The effect of both, however, is counteracted by setting up the instrument at a point equally distant from the two points sighted. Let the student prove this by means of a diagram.

One setting of the level is usually sufficient, provided that the two points are visible from the point where the level is set up, and

* A Y-level, and any good level, or a transit with telescope-bubble, may be used.

are not much over 1000 ft. apart, and their difference of elevation is not greater than 14 or 15 ft. In other cases we proceed as follows:

215. Suppose the difference of elevation between any two points, *A* and *H* in Fig. 71, is required.

Set up the instrument at some point equally distant from the initial point *A* and some other point, *B*, where it will be convenient to hold the rod. No appreciable error will be made if the instrument is not exactly equally distant from *A* and *B*, it being sufficient for the surveyor to judge the distances by the eye, or to let the rodman step off the distances. If haste rather than accuracy is desired,

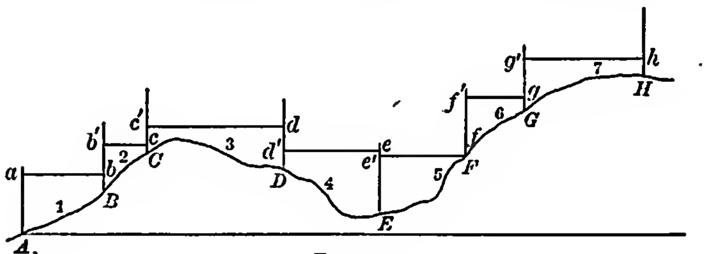


FIG. 71

no effort need be made to put the instrument midway between the points where the rod is held. Where very great precision is desired, a correction for both curvature and refraction should be applied. No effort is made to hold the rod on the line between *A* and *H*, and the instrument is seldom exactly on the line between *A* and *B*, or *B* and *C*, etc., but unnecessary deviation from a direct line is to be avoided.

Now get the line of sight on the rod at *A* and take the reading, in this case 9.5 (feet), which is usually termed a back-sight, but which we shall call a *plus* sight; then revolve the telescope and read the rod held at *B*, 2.6, which is usually called a *fore-sight*, but which we shall call a *minus* sight,* in accordance with the following definitions:

A *plus sight*, or reading, is any reading taken on a point of known or assumed elevation for the purpose of determining the elevation of the instrument (that is, of the line of sight).

A *minus sight*, or reading, is any reading taken for the purpose of determining the elevation of the (unknown) point on which the rod is held.

Having noted these + and − sights in their proper column, as

* The terms "back-sight" and "fore-sight," while still used by many surveyors, are misleading. The author has often seen a beginner puzzled over getting a "fore-sight" when the telescope is pointing *back* along the line, and *vice versa*.

shown in the form for field notes given below, move the instrument to a position, "2," in advance of *B*, take the reading (+7.3) of the rod held at *B*, and then the reading (−1.1) of the rod at *C*.

FORM OF RECORD FOR DIFFERENTIAL LEVELING

No. of Sta.	+S.	−S.	B.M. +	B.M. −	Remarks
1	9.5	2.6	8.24		B.M. near *A* is 100 ft. above datum plane.
2	7.3	1.1			
3	4.0	6.2			
4	2.3	9.7			
5	9.0	0.7			
6	9.5	2.1			
7	7.1	2.6		2.84	on B.M. near *H*.
	+ 48.7	− 25.0			
	− 25.0				
	+ 23.7				

Move the instrument to position number "3" and proceed as before, and so on till the last (minus) sight is taken on the rod held at *H*.

Then the *algebraic* sum of all the readings equals the difference of elevation of *A* and *H*. In this case the difference of elevation $= +23.7$, which shows that the last point, *H*, is higher than *A*.

Should the difference of elevation of any intermediate points, as *B* and *E*, be desired, we simply take the algebraic sum of the + and − sights in the 2d, 3d, and 4th rows above, giving $+13.6 - 17.0 = -3.4$, the minus sign showing that *E* is below *B*.

216. Instruments. — To obtain the best results the instrument used should be adjusted every day, and the turning-points should be on firm ground. The rodman must hold the rod vertically. The best way to do this is to stand behind the rod and hold it loosely between the hands, so that it will balance itself.* This is easily done if the wind is not high. If a target rod is used, the rodman sets the target, the observer directing him by a motion of the hand, up or down, till the zero of the target is on the line of sight, when the rodman records the reading in his note-book.

* In precise work, rod-levels are used which, by the position of the bubble, show when the rod is vertical.

If a self-reading rod is used, the observer reads the rod, and records the reading in his note-book. Greater speed can be made with a self-reading rod.

There are many different forms of levels, some of which are described in Chapter I, where will also be found a description of two leveling-rods (Art. 96).

217. Bench-marks and Turning-points. — *Bench-marks* are fixed points whose elevations are known or assumed to be known. *Turning-points* are temporary bench-marks, and serve as reference points when the instrument is moved and set up elsewhere. All the intermediate points, *B*, *C*, *D*, etc., in the last example, are really turning-points. Their position (as to elevation) is fixed by the *minus* (or fore) sight taken before the instrument is moved. Then, after the instrument is moved, the next point is determined with reference to this turning-point, and so on.

A bench-mark (B. M.) is denoted in various ways, such as a stake driven in the ground, a spike in the root of a tree, a stone pillar, or a point on a natural rock.

A turning-point (T. P.) is usually something less durable, as a small peg, or even the hard crust of a roadbed.

In the field notes, usually under the head of remarks, the exact position of all bench-marks should be described. In important work the bench-mark should be of so permanent a character and so well described that a surveyor could find it many years later.

If getting the difference of elevation between two points occupies only a few hours, bench-marks may be unnecessary, but, if the work is interrupted, as for dinner or at nightfall, a bench-mark must be established and its position recorded in the note-book.

PROFILE LEVELING

218. In *profile leveling* the object is to get the profile of certain lines established on the ground.

Such a profile is needed in many kinds of work, such as obtaining the grade of a railroad, highway, water-pipe, or drain-pipe line. Profile leveling differs from differential leveling in that the distance from some initial point of each position of the rod, which is always held on certain lines, is recorded together with the elevation of the point above a certain *datum plane*.

This *datum plane* is usually taken a certain number of feet below a well-defined bench-mark, and, to avoid minus signs, it is best to

assume it lower than the lowest point of the profile,* preferably an even hundred of feet below the bench-mark.

219. In profile leveling the height of the instrument is first obtained by taking a reading on a rod held upon a bench-mark, the height of this B. M. above the plane assumed as a datum plane being known. This reading upon the B. M. is a *plus* sight, and the height of the instrument (H. I.) is this reading added to the elevation of the B. M.

The rod is now held at some point on the line; if at the beginning this may be called station "0." This is a minus sight, and is recorded on the second line, opposite station "0." We give below a form of reduction, which differs but little from a sample page given in Johnson's

FORM OF RECORD FOR PROFILE LEVELING

+ S.	B. M. or T. P.	H. I.	− S.	S. E.	STATIONS	REMARKS
2.810	100.00	102.810			B. M. (*a*)	
			5.81	97.00	0	
			8.61	94.20	1	
			9.94	92.87	2	
1.620	92.315	93.935	10.495		B. M. (*b*)	
			2.96	90.97	3	
			1.80	92.13	3 + 40	
			4.90	89.03	4	
			5.27	88.66	6	
1.481	89.657	91.138	4.278		B. M. (*c*)	
			4.62	86.51	7	
			3.12	88.01	8	
3.355	88.658	92.013	2.48		T. P.	
			2.07	89.94	9	
			4.20	87.81	10	
			6.20	85.81	11	
	86.540		5.473		B. M. (*d*)	

In the above form + S. denotes plus sight; − S., minus sight; B.M., bench-mark; T.P., turning-point; H.I., height of instrument; S.E., surface elevation.

"Surveying."† This form requires six columns, all of which can be put on the left-hand page of the note-book, leaving the right-hand page for remarks. The 1st, 4th, and 6th columns are taken in the

* In tide-water country, the elevation of mean tide is often assumed as the datum plane.

† A contribution to the *Engineering News* by Mr. E. S. Walters, a railroad engineer.

field; the 2d, 3d, and 5th can be filled in afterwards. The calculation is so simple that the surveyor can usually find time to complete these in the field, and thus often has an opportunity to detect errors on the spot. Under the head of "Remarks," the surveyor writes out full information in regard to bench-marks, etc. In this example, the first and last bench-marks are thus described:

B. M. (*a*), southwest corner lower step, front door Library, cross (X) in stone. B. M. (*d*), an iron spike in stump, 2′ from sidewalk in Elliott Park, nearly opposite Miss Elliott's cottage.

220. The work moves along more rapidly if the line is measured out previously and stakes are set at distances of 100 ft., or wherever it is deemed expedient to take the elevation.

Sometimes, generally on account of an abrupt change in the ground, it is desirable to take readings at shorter distances than 100 ft.; the distance is then called a *plus*. In our notes there is such a point at the distance of 340 ft., which is recorded as station "3+40." In like manner "26+30" would denote a station 2630 ft. from the starting-point.

If at any point the elevation changes very little, the rod need not be held at every 100 ft. mark. In our example, station "5" is not given, and an examination of the S. E. column shows that there is but little change between 400 and 600 ft. In this instance, a B. M. was usually made instead of a T. P. when the instrument was moved, because these points were at the intersection of side streets, and bench-marks were left for reference in running profiles of these streets. The H. I. values are necessary to deduce the S. E. values, and must be recorded; but the elevations of turning-points, being steps in the calculation of the H. I., need not necessarily be recorded.

The elevations given in column 2 are not inserted in column 5 because they form no part of the surface elevations that are sought. Occasionally a T. P. may coincide with a station, in which case the − S. of the T. P. is the same as the − S. of a station, and the elevation of that T. P. is the same as the S. E. of the station; but, to avoid confusion, it is best to record the readings in separate lines.

221. To get the H. I. in first position, we add the +S. to the elevation of the B. M.

To get the H. I. in second position,* add to the elevation of

* Caution. — Before moving the instrument, be sure to take a sight (a minus sight) on the next T. P. or B. M. After the instrument is set up, the first sight taken is the plus sight on this T. P. or B. M.

B. M. (*b*) the + S.; or, regardless of sign, subtract from the first H. I. the −S. and add to the result the +S. of the B. M. (that is, add algebraically to the first H. I. the −S. and +S. of the T. P. or B. M.); thus,

$$102.810 - 10.495 + 1.620 = 93.935.$$

For the H. I. in third position,

$$93.935 - 4.278 + 1.481 = 91.138,$$

and so on.

The surface elevations are obtained by subtracting numerically (or adding algebraically) the minus sights from the last H.I. found; thus

$$\text{S. E. at } 0 = 102.81 - 5.81 = 97.00;$$

$$\text{S. E. at } 1 = 102.81 - 8.61 = 94.20;$$

$$\text{S. E. at } 2 = 102.81 - 9.94 = 92.87;$$

$$\text{S. E. at } 3 = \ \ 93.93 - 2.96 = 90.97;$$

etc.

Readings on bench-marks or turning-points are taken to thousandths, other readings to hundredths, and the surface elevations are computed to hundredths, or often only to tenths.

In the field notes below, fill out properly the 2d, 3d, and 5th columns. The field practice of the student will furnish many similar examples.

EXAMPLE

+ S.	B. M. OR T. P.	H. I.	− S.	S. E.	STATIONS
0.673	50.000	50.673			B. M.
			1.00		0
			0.90		1
			5.60		2
			12.80		2 + 90
			6.62		3 + 50
11.482			5.631		T. P.
			8.80		5
12.043			1.632		T. P.
			10.23		6
			5.00		7
			3.30		8
11.692		(78.071)	0.556		T. P.
			8.52		9
			6.20		10

ESTABLISHING A GRADE LINE

222. The final grade depends upon the character of the ground and the purpose for which the line is run. A grade that will answer for a highway is often much too steep for a railroad. It might be expedient to spend thousands of dollars to reduce the grade of a railroad while it would be folly to spend a hundred dollars to lessen a similar grade on a highway. It is beyond the scope of this work to discuss the various conditions that should have weight in deciding upon the grade to be adopted.

One example is sufficient to give an idea of the process of establishing a grade line after the surface elevations have been obtained, as in Art. 219. The following is a suitable reduction form:*

STATIONS	S. E.	GRADE	CUT +	FILL −	REMARKS
0	41.0	41.0	0.0	0.0	
1	40.5	38.7	1.8		
2	40.5	36.4	4.1		
3	33.6	34.1		0.5	0 at 2.96
3 + 40	29.5	33.0		3.5	
4	32.6	31.6	1.0		0 at 3.90
5	35.2	29.4	5.8		
6	32.0	27.0	5.0		
7	21.0	24.6		3.6	0 at 6.64
8	16.0	22.3		6.3	
9	19.8	19.8	0.0	0.0	

223. The Grade Line. — Figure 72 is the profile of the above. Suppose the grade must not be steeper than 2.5 in 100. The difference of elevation between "0" and "9" is 21.2 ft. Now 21.2 in 900 is 2.36 in 100, which is within our limit. Moreover, by drawing a line from "0" to "9," we observe that the excavation and embankment are not very different, the cuts being a little in excess of the fills; this is

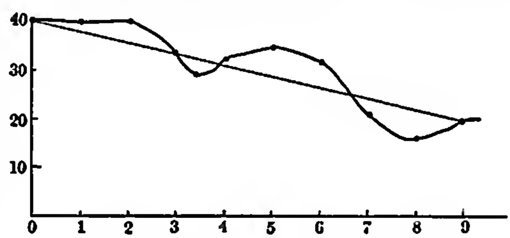


FIG. 72

* This is evidently not from the profile of Art. 219. These surface elevations were deduced from a similar profile.

usually an advantage, as most earth shrinks when excavated and removed.

Having determined on the grade line, the column of grade heights (column 3) is easily filled out either by allowing a descent of 2.36 ft. from the "0" point for each 100 ft., or by taking the grade numerals at once from the diagram (Fig. 72) by means of the proper scale.

If coördinate paper is used, this graphic method is very rapid and in most cases sufficiently accurate.

It is customary to use a larger scale for the vertical than for the horizontal distances, thus magnifying the inequalities of the profile. If this were not done, only very large inequalities would show on the diagram. The scale used in Fig. 72 is a very suitable one; viz. for the horizontal, 1 in. to 100 ft., and for the vertical, 1 in. to 10 ft.

It is often economical and advantageous, for other reasons, to change the grade even within the short space of a few hundred feet.

TOPOGRAPHICAL LEVELING

224. In topographical surveying it is necessary to determine the distances of points above (or below) a certain datum plane, as well as to find their positions with reference to certain fixed lines, such as a meridian and a parallel of latitude, the latter measurements being made in a horizontal plane.

The objects of such a survey are many. A topographical survey over the proposed route of a railroad should be made in order that a safe, economic road be constructed. Whenever a town or city is to be laid out, a topographical survey is absolutely necessary if the best results are to be obtained in locating streets and selecting the routes for water and sewer pipes.

When a ravine is to be converted into a reservoir by a dam thrown across it, a topographical survey furnishes the means of telling to what distance the water will back up the ravine and of calculating the contents of the reservoir.

Such a survey will likewise furnish the data for computing the amount of earth to be excavated in making a reservoir, leveling a field for an athletic ground, or for any other purpose.

225. Topographical leveling consists essentially in getting a series of profiles of the ground to be surveyed. There are several methods arising from the different arrangements of this series of profiles and from the instruments used.

The old method of getting the elevations of each point, derived by means of a level and measuring the horizontal distances with a chain, or tape, and getting azimuths or bearings with a transit or compass, is accurate, but very laborious and costly, and is chiefly employed when the area of the survey is very limited and great accuracy is required.

The plane-table, either with or without stadia wires, has been very extensively used for this purpose. Both of these methods are being superseded by the stadia method, in which the transit and stadia rods are the only instruments used. The azimuths, distances, and elevations are quickly obtained. (See Chapter V, iii.)

If the work is based on a rigid triangulation system, the accuracy of this method is usually all that is desired. We cannot enter into any description of the field work, but what has already been said under the heads of transit surveying, stadia work, and profile leveling will serve as a guide to the student or surveyor who undertakes such work.

226. Grading. — A very simple method of grading, or finding the amount of excavation or embankment, is as follows:

Divide the area into rectangles (Fig. 73), the longer sides of which should not be over 50 ft. on ordinary rolling ground, and drive pegs at the corners. Find the elevation at each intersection by means of a level, referring the elevations to some datum plane below the surface after it is graded. Subtract from these readings the elevations of the corresponding points on the graded surface. The several differences are the depths of excavation (or fill) at the corners. The contents of any partial volume is the mean of the four corner heights multiplied by the area of its cross-section. Now, since the rectangular areas were made equal, and since each corner height will be used as many times as there are rectangles joining at that corner, we have, in cubic yards,

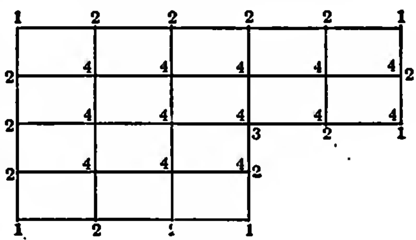


FIG. 73

$$V = \frac{A}{4 \times 27}[\Sigma h_1 + 2\,\Sigma h_2 + 3\,\Sigma h_3 + 4\,\Sigma h_4],$$

where V = the contents sought, A = area of each cross-section, Σh_1 = the sum of all the corner heights that stand alone, Σh_2 = the sum

of all the corner heights common to *two* rectangles, etc., the subscripts denoting the number of adjoining rectangles.

Hence we have the

RULE. — Take each corner height as many times as there are partial areas adjoining it, add them all together, and multiply by one-fourth of the area of a single rectangle. This gives the volume in cubic feet. To obtain it in cubic yards, divide by twenty-seven.

The calculation is simplified if the ground be laid out in rectangles 30 ft. by 36 ft., for then

$$\frac{A}{4 \times 27} = \frac{1080}{108} = 10.$$

TABLES

TABLES

THE first ten tables will be found in the body of the book, as follows:

TABLE XI

(1) LINEAR MEASURE

12 inches (in.)	make 1 foot	ft.
3 ft.	make 1 yard	yd.
5½ yd.	make 1 rod or pole	rd. or p.
40 rd.	make 1 furlong	fur.
8 fur.	make 1 mile	mi.

Equivalents

mi.	fur.	rd.	yd.	ft.
1 =	8 =	320 =	1760 =	5280
	1 =	40 =	220 =	660
		1 =	5½ =	16½
			1 =	3

(2) SURVEYORS' LINEAR MEASURE

7.92 inches	make 1 link	l.
25 l.	make 1 rod or pole	rd. or p.
4 rd., or 66 ft.,	make 1 chain	ch.
80 ch.	make 1 mile	mi.

Equivalents

mi.	ch.	rd.	ft.
1 =	80 =	320 =	5280
	1 =	4 =	66
		1 =	16½

(3) Square Measure

144 square inches (sq. in.)	make 1 square foot . .	sq. ft.
9 sq. ft.	make 1 square yard . .	sq. yd.
30¼ sq. yd.	make 1 square rod . .	sq. rd.
40 sq. rd.	make 1 rood	R.
4 R.	make 1 acre	A.
640 A.	make 1 square mile . .	sq. mi.

Equivalents

A.	R.	sq. rd.	sq. yd.	sq. ft.
1 =	4 =	160 =	4840 =	43560
	1 =	40 =	1210 =	10890
		1 =	30¼ =	272¼
			1 =	9

(4) Surveyors' Square Measure

625 square links	make 1 pole (sq. rd.) . .	P.
16 P.	make 1 square chain . .	sq. ch.
10 sq. ch.	make 1 acre	A.
640 A.	make 1 square mile . . .	sq. mi.
36 sq. mi.	make 1 township . . .	Tp.

(5) Cubic Measure

1728 cubic inches (cu. in.)	make 1 cubic foot . .	cu. ft.
27 cu. ft.	make 1 cubic yard . .	cu. yd.
16 cu. ft.	make 1 cord foot . .	cd. ft.
8 cd. ft. or 128 cu. ft.	make 1 cord of wood .	cd.
24¾* cu. ft.	make 1 perch of stone .	Pch.

METRIC SYSTEM

(6) Linear Measure

10 millimetres = 1 centimetre
10 centimetres = 1 decimetre
10 decimetres = 1 metre
10 metres = 1 dekametre
10 dekametres = 1 hektometre
10 hektometres = 1 kilometre
10 kilometres = 1 myriametre.

(7) Square Measure

100 square millimetres = 1 square centimetre
100 square centimetres = 1 square decimetre
100 square decimetres = 1 square metre
100 square metres = 1 square dekametre
100 square dekametres = 1 square hektometre
100 square hektometres = 1 square kilometre

* Varies in different localities.

Also, A centare = a square metre
An are = a square dekametre, or 100 centares
A hektare = a square hektometre, or 100 ares

NOTE.—The *square metre* is used in measuring ordinary surfaces; the *square kilometre*, in measuring the areas of countries; the *are* and *hektare*, in measuring land.

(8) CUBIC MEASURE

1000 cubic millimetres = 1 cubic centimetre
1000 cubic centimetres = 1 cubic decimetre
1000 cubic decimetres = 1 cubic metre

The following terms are also used:

A decistere = .1 cubic metre
A stere = 1 cubic metre, or 10 decisteres

NOTE.—The *cubic metre* is used in measuring ordinary solids; the *stere*, in measuring wood.

(9) FOR CONVERTING METRES, FEET, AND CHAINS

METRES TO FEET		FEET TO METRES AND CHAINS			CHAINS TO FEET	
Metres	Feet	Feet	Metres	Chains	Chains	Feet
1	3.28087	1	0.304797	0.0151	0.01	0.66
2	6.56174	2	0.609595	.0303	.02	1.32
3	9.84261	3	0.914392	.0455	.03	1.98
4	13.12348	4	1.219189	.0606	.04	2.64
5	16.40435	5	1.523986	.0758	.05	3.30
6	19.68522	6	1.828784	.0909	.06	3.96
7	22.96609	7	2.133581	.1061	.07	4.62
8	26.24695	8	2.438378	.1212	.08	5.28
9	29.52782	9	2.743175	.1364	.09	5.94
10	32.80869	10	3.047973	.1515	.10	6.60
20	65.61739	20	6.095946	.3030	.20	13.20
30	98.42609	30	9.143918	.4545	.30	19.80
40	131.2348	40	12.19189	.6061	.40	26.40
50	164.0435	50	15.23986	.7576	.50	33.00
60	196.8522	60	18.28784	.9091	.60	39.60
70	229.6609	70	21.33581	1.0606	.70	46.20
80	262.4695	80	24.38378	1.2121	.80	52.80
90	295.2782	90	27.43175	1.3636	.90	59.40
100	328.0869	100	30.47973	1.5151	1	66.00
200	656.1739	200	60.95946	3.0303	2	132
300	984.2609	300	91.43918	4.5455	3	198
400	1312.348	400	121.9189	6.0606	4	264
500	1640.435	500	152.3986	7.5756	5	330
600	1968.522	600	182.8784	9.0909	6	396
700	2296.609	700	213.3581	10.606	7	462
800	2624.695	800	243.8378	12.121	8	528
900	2952.782	900	274.3175	13.636	9	594
1000	3280.869	1000	304.7973	15.151	10	660
2000	6561.739	2000	609.5946	30.303	20	1320
3000	9842.609	3000	914.3918	45.455	30	1980
4000	13123.48	4000	1219.189	60.606	40	2640
5000	16404.35	5000	1523.986	75.756	50	3300
6000	19685.22	6000	1828.784	90.909	60	3960
7000	22966.09	7000	2133.581	106.06	70	4620
8000	26246.95	8000	2438.378	121.21	80	5280
9000	29527.82	9000	2743.175	136.36	90	5940

TABLE XII

Mensuration Formulæ

In these formulæ, $S =$ area; $h =$ altitude; a, b, c, sides of a triangle; $r =$ radius of circle.

(1) Triangle, base and altitude given, $S = \frac{1}{2} bh$.

(2) Triangle, the three sides given,

$$s = \tfrac{1}{2}(a + b + c),$$

$$S = \sqrt{s(s-a)(s-b)(s-c)}.$$

(3) Trapezoid, a and b being the parallel sides, $S = \frac{1}{2}(a + b)h$.

(4) Parallelogram, $S = bh$.

(5) Circle, $S = \pi r^2$ $(\pi = 3.1416)$.

In the following, S=surface; V=volume; H=altitude; L=slant height; R = radius of base; B = area of base; P = perimeter of base.

(6) For prism, $S = PH$, $V = B \times H$.

(7) For pyramid, $S = \frac{1}{2} PL$, $V = \frac{1}{3} B \times H$.

(8) For cylinder, $S = 2\pi RH$, $V = \pi R^2 H$.

(9) For cone, $S = \pi RL$, $V = \frac{1}{3}\pi R^2 H$.

(10) For sphere, $S = 4\pi R^2$, $V = \frac{4}{3}\pi R^3$.

TABLE XIII

Trigonometric Formulæ

In the formulæ below, a, b, c denote the sides of the triangle ABC opposite the angles A, B, C, respectively; $s = \frac{1}{2}(a+b+c)$, and S = area of the triangle.

(i) To solve a right-angled plane triangle ($C = 90°$), use one or more of the following formulæ:

$$\sin A = \frac{a}{c},\quad \cos A = \frac{b}{c},\quad \tan A = \frac{a}{b},\quad \cot A = \frac{b}{a},$$

$$\sin B = \frac{b}{c},\quad \cos B = \frac{a}{c},\quad \tan B = \frac{b}{a},\quad \cot B = \frac{a}{b},$$

$$c^2 = a^2 + b^2,\quad A = 90° - B,\quad B = 90° - A.$$

(ii) Oblique triangles may be solved by some of the following formulæ:

	Given	Sought	Formulæ
(1)	A, B, a	C, b, c	$C = 180° - (A+B)$, $b = \frac{a}{\sin A}\sin B$, $c = \frac{a}{\sin A}\sin(A+B)$.
(2)	A, a, b	B, C, c	$\sin B = \frac{\sin A}{a} b$, $C = 180° - (A+B)$, $c = \frac{a \sin C}{\sin A}$,
(3)	C, a, b	A, B, c	$\frac{1}{2}(A+B) = 90° - \frac{1}{2}C$, $\tan\frac{1}{2}(A-B) = \frac{a-b}{a+b}\tan\frac{1}{2}(A+B)$, $A = \frac{1}{2}(A+B) + \frac{1}{2}(A-B)$, $B = \frac{1}{2}(A+B) - \frac{1}{2}(A-B)$, $c = (a+b)\frac{\cos\frac{1}{2}(A+B)}{\cos\frac{1}{2}(A-B)}$, $S = \frac{1}{2}ab\sin C$.
(4)	a, b, c	A, etc.	$\sin\frac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{bc}}$, $\cos\frac{1}{2}A = \sqrt{\frac{s(s-a)}{bc}}$, $\tan\frac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$, $S = \sqrt{s(s-a)(s-b)(s-c)}$.

TABLE XIV

Squares, Cubes, Square Roots, and Cube Roots

No.	Square	Cube	Sq. Root	Cu. Root	No.	Square	Cube	Sq. Root	Cu. Root
1	1	1	1.0000	1.0000	51	2601	132651	7.1414	3.7084
2	4	8	1.4142	1.2599	52	2704	140608	7.2111	3.7325
3	9	27	1.7320	1.4422	53	2809	148877	7.2801	3.7563
4	16	64	2.0000	1.5874	54	2916	157464	7.3485	3.7798
5	25	125	2.2361	1.7100	55	3025	166375	7.4162	3.8030
6	36	216	2.4495	1.8171	56	3136	175616	7.4833	3.8259
7	49	343	2.6458	1.9129	57	3249	185193	7.5498	3.8485
8	64	512	2.8284	2.0000	58	3364	195112	7.6158	3.8709
9	81	729	3.0000	2.0801	59	3481	205379	7.6811	3.8930
10	100	1000	3.1623	2.1544	60	3600	216000	7.7460	3.9149
11	121	1331	3.3166	2.2240	61	3721	226981	7.8102	3.9365
12	144	1728	3.4641	2.2894	62	3844	238328	7.8740	3.9579
13	169	2197	3.6056	2.3513	63	3969	250047	7.9373	3.9791
14	196	2744	3.7417	2.4101	64	4096	262144	8.0000	4.0000
15	225	3375	3.8730	2.4662	65	4225	274625	8.0623	4.0207
16	256	4096	4.0000	2.5198	66	4356	287496	8.1240	4.0412
17	289	4913	4.1231	2.5713	67	4489	300763	8.1854	4.0615
18	324	5832	4.2426	2.6207	68	4624	314432	8.2462	4.0817
19	361	6859	4.3589	2.6684	69	4761	328509	8.3066	4.1016
20	400	8000	4.4721	2.7144	70	4900	343000	8.3666	4.1213
21	441	9261	4.5826	2.7589	71	5041	357911	8.4261	4.1408
22	484	10648	4.6904	2.8020	72	5184	373248	8.4853	4.1602
23	529	12167	4.7958	2.8439	73	5329	389017	8.5440	4.1793
24	576	13824	4.8990	2.8845	74	5476	405224	8.6023	4.1983
25	625	15625	5.0000	2.9240	75	5625	421875	8.6603	4.2172
26	676	17576	5.0990	2.9625	76	5776	438976	8.7178	4.2358
27	729	19683	5.1962	3.0000	77	5929	456533	8.7750	4.2543
28	784	21952	5.2915	3.0366	78	6084	474552	8.8318	4.2727
29	841	24389	5.3852	3.0723	79	6241	493039	8.8882	4.2908
30	900	27000	5.4772	3.1072	80	6400	512000	8.9443	4.3089
31	961	29791	5.5678	3.1414	81	6561	531441	9.0000	4.3267
32	1024	32768	5.6569	3.1748	82	6724	551368	9.0554	4.3445
33	1089	35937	5.7446	3.2075	83	6889	571787	9.1104	4.3621
34	1156	39304	5.8310	3.2396	84	7056	592704	9.1652	4.3795
35	1225	42875	5.9161	3.2711	85	7225	614125	9.2195	4.3968
36	1296	46656	6.0000	3.3019	86	7396	636056	9.2136	4.4140
37	1369	50653	6.0828	3.3322	87	7569	658503	9.3274	4.4310
38	1444	54872	6.1644	3.3620	88	7744	681472	9.3808	4.4480
39	1521	59319	6.2450	3.3912	89	7921	704969	9.4340	4.4647
40	1600	64000	6.3246	3.4200	90	8100	729000	9.4868	4.4814
41	1681	68921	6.4031	3.4482	91	8281	753571	9.5394	4.4979
42	1764	74088	6.4807	3.4760	92	8464	778688	9.5917	4.5144
43	1849	79507	6.5574	3.5034	93	8649	804357	9.6437	4.5307
44	1936	85184	6.6332	3.5303	94	8836	830584	9.6954	4.5468
45	2025	91125	6.7082	3.5569	95	9025	857375	9.7468	4.5629
46	2116	97336	6.7823	3.5830	96	9216	884736	9.7980	4.5789
47	2209	103823	6.8557	3.6088	97	9409	912673	9.8489	4.5947
48	2304	110592	6.9282	3.6342	98	9604	941192	9.8995	4.6104
49	2401	117649	7.0000	3.6593	99	9801	970299	9.9499	4.6261
50	2500	125000	7.0711	3.6840	100	10000	1000000	10.0000	4.6416

TABLE XV

CHORDS*

°	0′	10′	20′	30′	40′	50′	d.
0	0.0000	0.0029	0.0058	0.0087	0.0116	0.0145	29
1	0.0175	0.0204	0.0233	0.0262	0.0291	0.0320	29
2	0.0349	0.0378	0.0407	0.0436	0.0465	0.0494	29
3	0.0524	0.0553	0.0582	0.0611	0.0640	0.0669	29
4	0.0698	0.0727	0.0756	0.0785	0.0814	0.0843	29
5	0.0872	0.0901	0.0931	0.0960	0.0989	0.1018	29
6	0.1047	0.1076	0.1105	0.1134	0.1163	0.1192	29
7	0.1221	0.1250	0.1279	0.1308	0.1337	0.1366	29
8	0.1395	0.1424	0.1453	0.1482	0.1511	0.1540	29
9	0.1569	0.1598	0.1627	0.1656	0.1685	0.1714	29
10	0.1743	0.1772	0.1801	0.1830	0.1859	0.1888	29
11	0.1917	0.1946	0.1975	0.2004	0.2033	0.2062	29
12	0.2091	0.2119	0.2148	0.2177	0.2206	0.2235	29
13	0.2264	0.2293	0.2322	0.2351	0.2380	0.2409	29
14	0.2437	0.2466	0.2495	0.2524	0.2553	0.2582	29
15	0.2611	0.2639	0.2668	0.2697	0.2726	0.2755	29
16	0.2783	0.2812	0.2841	0.2870	0.2899	0.2927	29
17	0.2956	0.2985	0.3014	0.3042	0.3071	0.3100	29
18	0.3129	0.3157	0.3186	0.3215	0.3244	0.3272	29
19	0.3301	0.3330	0.3358	0.3387	0.3416	0.3444	29
20	0.3473	0.3502	0.3530	0.3559	0.3587	0.3616	29
21	0.3645	0.3673	0.3702	0.3730	0.3759	0.3788	28
22	0.3816	0.3845	0.3873	0.3902	0.3930	0.3959	28
23	0.3987	0.4016	0.4044	0.4073	0.4101	0.4130	28
24	0.4158	0.4187	0.4215	0.4244	0.4272	0.4300	28
25	0.4329	0.4357	0.4386	0.4414	0.4442	0.4471	28
26	0.4499	0.4527	0.4556	0.4584	0.4612	0.4641	28
27	0.4669	0.4697	0.4725	0.4754	0.4782	0.4810	28
28	0.4838	0.4867	0.4895	0.4923	0.4951	0.4979	28
29	0.5008	0.5036	0.5064	0.5092	0.5120	0.5148	28
30	0.5176	0.5204	0.5233	0.5261	0.5289	0.5317	28
31	0.5345	0.5373	0.5401	0.5429	0.5457	0.5485	28
32	0.5513	0.5541	0.5569	0.5597	0.5625	0.5652	28
33	0.5680	0.5708	0.5736	0.5764	0.5792	0.5820	28
34	0.5847	0.5875	0.5903	0.5931	0.5959	0.5986	28
35	0.6014	0.6042	0.6070	0.6097	0.6125	0.6153	28
36	0.6180	0.6208	0.6236	0.6263	0.6291	0.6319	28
37	0.6346	0.6374	0.6401	0.6429	0.6456	0.6484	28
38	0.6511	0.6539	0.6566	0.6594	0.6621	0.6649	28
39	0.6676	0.6704	0.6731	0.6758	0.6786	0.6813	27
40	0.6840	0.6868	0.6895	0.6922	0.6950	0.6977	27
41	0.7004	0.7031	0.7059	0.7086	0.7113	0.7140	27
42	0.7167	0.7195	0.7222	0.7249	0.7276	0.7303	27
43	0.7330	0.7357	0.7384	0.7411	0.7438	0.7465	27
44	0.7492	0.7519	0.7546	0.7573	0.7600	0.7627	27
45	0.7654	0.7681	0.7707	0.7734	0.7761	0.7788	27
46	0.7815	0.7841	0.7868	0.7895	0.7922	0.7948	27
47	0.7975	0.8002	0.8028	0.8055	0.8082	0.8108	27
48	0.8135	0.8161	0.8188	0.8241	0.8241	0.8267	26
49	0.8294	0.8320	0.8347	0.8373	0.8400	0.8426	26
50	0.8452	0.8479	0.8505	0.8531	0.8558	0.8584	26
51	0.8610	0.8636	0.8663	0.8689	0.8715	0.8741	26
52	0.8767	0.8794	0.8820	0.8846	0.8872	0.8898	26
53	0.8924	0.8950	0.8976	0.9002	0.9028	0.9054	26
54	0.9080	0.9106	0.9132	0.9157	0.9183	0.9209	26
55	0.9235	0.9261	0.9287	0.9312	0.9338	0.9364	26
56	0.9389	0.9415	0.9441	0.9466	0.9492	0.9518	26
57	0.9543	0.9569	0.9594	0.9620	0.9645	0.9671	26
58	0.9696	0.9722	0.9747	0.9772	0.9798	0.9823	25
59	0.9848	0.9874	0.9899	0.9924	0.9950	0.9975	25
	0′	10′	20′	30′	40′	50′	d.

P. P.

	30	29	28	27	26	25
1	3 0	2 9	2 8	2 7	2 6	2 5
2	6 0	5 8	5 6	5 4	5 2	5 0
3	9 0	8 7	8 4	8 1	7 8	7 5
4	12 0	11 6	11 2	10 8	10 4	10 0
5	15 0	14 5	14 0	13 5	13 0	12 5
6	18 0	17 4	16 8	16 2	15 6	15 0
7	21 0	20 3	19 6	18 9	18 2	17 5
8	24 0	23 2	22 4	21 6	20 8	20 0
9	27 0	26 1	25 2	24 3	23 4	22 5

* Taken from Gauss's Tables.

TABLE XV — *Concluded*

Chords

°	0′	10′	20′	30′	40′	50′	d.
60	1.0000	1.0025	1.0050	1.0075	1.0101	1.0126	25
61	1.0151	1.0176	1.0201	1.0226	1.0251	1.0276	25
62	1.0301	1.0326	1.0351	1.0375	1.0400	1.0425	25
63	1.0450	1.0475	1.0500	1.0524	1.0549	1.0574	25
64	1.0598	1.0623	1.0648	1.0672	1.0697	1.0721	25
65	1.0746	1.0771	1.0795	1.0819	1.0844	1.0868	24
66	1.0893	1.0917	1.0942	1.0966	1.0990	1.1014	24
67	1.1039	1.1063	1.1087	1.1111	1.1136	1.1160	24
68	1.1184	1.1208	1.1232	1.1256	1.1280	1.1304	24
69	1.1328	1.1352	1.1376	1.1400	1.1424	1.1448	24
70	1.1472	1.1495	1.1519	1.1543	1.1567	1.1590	24
71	1.1614	1.1638	1.1661	1.1685	1.1709	1.1732	24
72	1.1756	1.1779	1.1803	1.1826	1.1850	1.1873	23
73	1.1896	1.1920	1.1943	1.1966	1.1990	1.2013	23
74	1.2036	1.2060	1.2083	1.2106	1.2129	1.2152	23
75	1.2175	1.2198	1.2221	1.2244	1.2267	1.2290	23
76	1.2313	1.2336	1.2359	1.2382	1.2405	1.2428	23
77	1.2450	1.2473	1.2496	1.2518	1.2541	1.2564	23
78	1.2586	1.2609	1.2632	1.2654	1.2677	1.2699	23
79	1.2722	1.2744	1.2766	1.2789	1.2811	1.2833	22
80	1.2856	1.2878	1.2900	1.2922	1.2945	1.2967	22
81	1.2989	1.3011	1.3033	1.3055	1.3077	1.3099	22
82	1.3121	1.3143	1.3165	1.3187	1.3209	1.3231	22
83	1.3252	1.3274	1.3296	1.3318	1.3339	1.3361	22
84	1.3383	1.3404	1.3426	1.3447	1.3469	1.3490	22
85	1.3512	1.3533	1.3555	1.3576	1.3597	1.3619	21
86	1.3640	1.3661	1.3682	1.3704	1.3725	1.3746	21
87	1.3767	1.3788	1.3809	1.3830	1.3851	1.3872	21
88	1.3893	1.3914	1.3935	1.3956	1.3977	1.3997	21
89	1.4018	1.4039	1.4060	1.4080	1.4101	1.4122	21
90	1.4142	1.4163	1.4183	1.4204	1.4224	1.4245	20
91	1.4265	1.4285	1.4306	1.4326	1.4346	1.4367	20
92	1.4387	1.4407	1.4427	1.4447	1.4467	1.4487	20
93	1.4507	1.4527	1.4547	1.4567	1.4587	1.4607	20
94	1.4627	1.4647	1.4667	1.4686	1.4706	1.4726	20
95	1.4746	1.4765	1.4785	1.4804	1.4824	1.4843	20
96	1.4863	1.4882	1.4902	1.4921	1.4941	1.4960	19
97	1.4979	1.4998	1.5018	1.5037	1.5056	1.5075	19
98	1.5094	1.5113	1.5132	1.5151	1.5170	1.5189	19
99	1.5208	1.5227	1.5246	1.5265	1.5283	1.5302	19
100	1.5321	1.5340	1.5358	1.5377	1.5395	1.5414	18
101	1.5432	1.5451	1.5469	1.5488	1.5506	1.5525	18
102	1.5543	1.5561	1.5579	1.5598	1.5616	1.5634	18
103	1.5652	1.5670	1.5688	1.5706	1.5724	1.5742	18
104	1.5760	1.5778	1.5796	1.5814	1.5832	1.5849	18
105	1.5867	1.5885	1.5902	1.5920	1.5938	1.5955	18
106	1.5973	1.5990	1.6008	1.6025	1.6042	1.6060	17
107	1.6077	1.6094	1.6112	1.6129	1.6146	1.6163	17
108	1.6180	1.6197	1.6214	1.6231	1.6248	1.6265	17
109	1.6282	1.6299	1.6316	1.6333	1.6350	1.6366	17
110	1.6383	1.6400	1.6416	1.6433	1.6450	1.6466	17
111	1.6483	1.6499	1.6515	1.6532	1.6548	1.6564	16
112	1.6581	1.6597	1.6613	1.6629	1.6646	1.6662	16
113	1.6678	1.6694	1.6710	1.6726	1.6742	1.6758	16
114	1.6773	1.6789	1.6805	1.6821	1.6836	1.6852	16
115	1.6868	1.6883	1.6899	1.6915	1.6930	1.6946	16
116	1.6961	1.6976	1.6992	1.7007	1.7022	1.7038	15
117	1.7053	1.7068	1.7083	1.7098	1.7113	1.7128	15
118	1.7143	1.7158	1.7173	1.7188	1.7203	1.7218	15
119	1.7233	1.7247	1.7262	1.7277	1.7291	1.7306	15
	0′	10′	20′	30′	40′	50′	d.

P. P.

	26	25
1	2 6	2 5
2	5 2	5 0
3	7 8	7 5
4	10 4	10 0
5	13 0	12 5
6	15 6	15 0
7	18 2	17 5
8	20 8	20 0
9	23 4	22 5

	24	23
1	2 4	2 3
2	4 8	4 6
3	7 2	6 9
4	9 6	9 2
5	12 0	11 5
6	14 4	13 8
7	16 8	16 1
8	19 2	18 4
9	21 6	20 7

	22	21
1	2 2	2 1
2	4 4	4 2
3	6 6	6 3
4	8 8	8 4
5	11 0	10 5
6	13 2	12 6
7	15 4	14 7
8	17 6	16 8
9	19 8	18 9

	20	19
1	2 0	1 9
2	4 0	3 8
3	6 0	5 7
4	8 0	7 6
5	10 0	9 5
6	12 0	11 4
7	14 0	13 3
8	16 0	15 2
9	18 0	17 1

	18	17
1	1 8	1 7
2	3 6	3 4
3	5 4	5 1
4	7 2	6 8
5	9 0	8 5
6	10 8	10 2
7	12 6	11 9
8	14 4	13 6
9	16 2	15 3

	16	15	14
1	1 6	1 5	1 4
2	3 2	3 0	2 8
3	4 8	4 5	4 2
4	6 4	6 0	5 6
5	8 0	7 5	7 0
6	9 6	9 0	8 4
7	11 2	10 5	9 8
8	12 8	12 0	11 2
9	14 4	13 5	12 6

P. P.

TABLE XVI

Stadia Tables[1]

M.	0°		1°		2°		3°	
	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.
0′	100.00	0.00	99.97	1.74	99.88	3.49	99.73	5.23
2	100.00	0.06	99.97	1.80	99.87	3.55	99.72	5.28
4	100.00	0.12	99.97	1.86	99.87	3.60	99.71	5.34
6	100.00	0.17	99.96	1.92	99.87	3.66	99.71	5.40
8	100.00	0.23	99.96	1.98	99.86	3.72	99.70	5.46
10	100.00	0.29	99.96	2.04	99.86	3.78	99.69	5.52
12	100.00	0.35	99.96	2.09	99.85	3.84	99.69	5.57
14	100.00	0.41	99.95	2.15	99.85	3.90	99.68	5.63
16	100.00	0.47	99.95	2.21	99.84	3.95	99.68	5.69
18	100.00	0.52	99.95	2.27	99.84	4.01	99.67	5.75
20	100.00	0.58	99.95	2.33	99.83	4.07	99.66	5.80
22	100.00	0.64	99.94	2.38	99.83	4.13	99.66	5.86
24	100.00	0.70	99.94	2.44	99.82	4.18	99.65	5.92
26	99.99	0.76	99.94	2.50	99.82	4.24	99.64	5.98
28	99.99	0.81	99.93	2.56	99.81	4.30	99.63	6.04
30	99.99	0.87	99.93	2.62	99.81	4.36	99.63	6.09
32	99.99	0.93	99.93	2.67	99.80	4.42	99.62	6.15
34	99.99	0.99	99.93	2.73	99.80	4.48	99.62	6.21
36	99.99	1.05	99.92	2.79	99.79	4.53	99.61	6.27
38	99.99	1.11	99.92	2.85	99.79	4.59	99.60	6.33
40	99.99	1.16	99.92	2.91	99.78	4.65	99.59	6.38
42	99.99	1.22	99.91	2.97	99.78	4.71	99.59	6.44
44	99.98	1.28	99.91	3.02	99.77	4.76	99.58	6.50
46	99.98	1.34	99.90	3.08	99.77	4.82	99.57	6.56
48	99.98	1.40	99.90	3.14	99.76	4.88	99.56	6.61
50	99.98	1.45	99.90	3.20	99.76	4.94	99.56	6.67
52	99.98	1.51	99.89	3.26	99.75	4.99	99.55	6.73
54	99.98	1.57	99.89	3.31	99.74	5.05	99.54	6.78
56	99.97	1.63	99.89	3.37	99.74	5.11	99.53	6.84
58	99.97	1.69	99.88	3.43	99.73	5.17	99.52	6.90
60	99.97	1.74	99.88	3.49	99.73	5.23	99.51	6.96
$c = 0.75$	0.75	0.01	0.75	0.02	0.75	0.03	0.75	0.05
$c = 1.00$	1.00	0.01	1.00	0.03	1.00	0.04	1.00	0.06
$c = 1.25$	1.25	0.02	1.25	0.03	1.25	0.05	1.25	0.08

[1] These tables, copied here by permission, were computed by Mr. Arthur Winslow of the State Geological Survey of Pennsylvania.

TABLE XVI — *Continued*

Stadia Tables

M.	4°		5°		6°		7°	
	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.
0′	99.51	6.96	99.24	8.68	98.91	10.40	98.51	12.10
2	99.51	7.02	99.23	8.74	98.90	10.45	98.50	12.15
4	99.50	7.07	99.22	8.80	98.88	10.51	98.48	12.21
6	99.49	7.13	99.21	8.85	98.87	10.57	98.47	12.26
8	99.48	7.19	99.20	8.91	98.86	10.62	98.46	12.32
10	99.47	7.25	99.19	8.97	98.85	10.68	98.44	12.38
12	99.46	7.30	99.18	9.03	98.83	10.74	98.43	12.43
14	99.46	7.36	99.17	9.08	98.82	10.79	98.41	12.49
16	99.45	7.42	99.16	9.14	98.81	10.85	98.40	12.55
18	99.44	7.48	99.15	9.20	98.80	10.91	98.39	12.60
20	99.43	7.53	99.14	9.25	98.78	10.96	98.37	12.66
22	99.42	7.59	99.13	9.31	98.77	11.02	98.36	12.72
24	99.41	7.65	99.11	9.37	98.76	11.08	98.34	12.77
26	99.40	7.71	99.10	9.43	98.74	11.13	98.33	12.83
28	99.39	7.76	99.09	9.48	98.73	11.19	98.31	12.88
30	99.38	7.82	99.08	9.54	98.72	11.25	98.29	12.94
32	99.38	7.88	99.07	9.60	98.71	11.30	98.28	13.00
34	99.37	7.94	99.06	9.65	98.69	11.36	98.27	13.05
36	99.36	7.99	99.05	9.71	98.68	11.42	98.25	13.11
38	99.35	8.05	99.04	9.77	98.67	11.47	98.24	13.17
40	99.34	8.11	99.03	9.83	98.65	11.53	98.22	13.22
42	99.33	8.17	99.01	9.88	98.64	11.59	98.20	13.28
44	99.32	8.22	99.00	9.94	98.63	11.64	98.19	13.33
46	99.31	8.28	98.99	10.00	98.61	11.70	98.17	13.39
48	99.30	8.34	98.98	10.05	98.60	11.76	98.16	13.45
50	99.29	8.40	98.97	10.11	98.58	11.81	98.14	13.50
52	99.28	8.45	98.96	10.17	98.57	11.87	98.13	13.56
54	99.27	8.51	98.94	10.22	98.56	11.93	98.11	13.61
56	99.26	8.57	98.93	10.28	98.54	11.98	98.10	13.67
58	99.25	8.63	98.92	10.34	98.53	12.04	98.08	13.73
60	99.24	8.68	98.91	10.40	98.51	12.10	98.06	13.78
$c = 0.75$	0.75	0.06	0.75	0.07	0.75	0.08	0.74	0.10
$c = 1.00$	1.00	0.08	0.99	0.09	0.99	0.11	0.99	0.13
$c = 1.25$	1.25	0.10	1.24	0.11	1.24	0.14	1.24	0.16

TABLE XVI — *Continued*

Stadia Tables

M.	8°		9°		10°		11°	
	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.
0′	98.06	13.78	97.55	15.45	96.98	17.10	96.36	18.73
2	98.05	13.84	97.53	15.51	96.96	17.16	96.34	18.78
4	98.03	13.89	97.52	15.56	96.94	17.21	96.32	18.84
6	98.01	13.95	97.50	15.62	96.92	17.26	96.29	18.89
8	98.00	14.01	97.48	15.67	96.90	17.32	96.27	18.95
10	97.98	14.06	97.46	15.73	96.88	17.37	96.25	19.00
12	97.97	14.12	97.44	15.78	96.86	17.43	96.23	19.05
14	97.95	14.17	97.43	15.84	96.84	17.48	96.21	19.11
16	97.93	14.23	97.41	15.89	96.82	17.54	96.18	19.16
18	97.92	14.28	97.39	15.95	96.80	17.59	96.16	19.21
20	97.90	14.34	97.37	16.00	96.78	17.65	96.14	19.27
22	97.88	14.40	97.35	16.06	96.76	17.70	96.12	19.32
24	97.87	14.45	97.33	16.11	96.74	17.76	96.09	19.38
26	97.85	14.51	97.31	16.17	96.72	17.81	96.07	19.43
28	97.83	14.56	97.29	16.22	96.70	17.86	96.05	19.48
30	97.82	14.62	97.28	16.28	96.68	17.92	96.03	19.54
32	97.80	14.67	97.26	16.33	96.66	17.97	96.00	19.59
34	97.78	14.73	97.24	16.39	96.64	18.03	95.98	19.64
36	97.76	14.79	97.22	16.44	96.62	18.08	95.96	19.70
48	97.75	14.84	97.20	16.50	96.60	18.14	95.93	19.75
40	97.73	14.90	97.18	16.55	96.57	18.19	95.91	19.80
42	97.71	14.95	97.16	16.61	96.55	18.24	95.89	19.86
44	97.69	15.01	97.14	16.66	96.53	18.30	95.86	19.91
46	97.68	15.06	97.12	16.72	96.51	18.35	95.84	19.96
48	97.66	15.12	97.10	16.77	96.49	18.41	95.82	20.02
50	97.64	15.17	97.08	16.83	96.47	18.46	95.79	20.07
52	97.62	15.23	97.06	16.88	96.45	18.51	95.77	20.12
54	97.61	15.28	97.04	16.94	96.42	18.57	95.75	20.18
56	97.59	15.34	97.02	16.99	96.40	18.62	95.72	20.23
58	97.57	15.40	97.00	17.05	96.38	18.68	95.70	20.28
60	97.55	15.45	96.98	17.10	96.36	18.73	95.68	20.34
$c = 0.75$	0.74	0.11	0.74	0.12	0.74	0.14	0.73	0.15
$c = 1.00$	0.99	0.15	0.99	0.16	0.98	0.18	0.98	0.20
$c = 1.25$	1.23	0.18	1.23	0.21	1.23	0.23	1.22	0.25

TABLE XVI — *Continued*

Stadia Tables

M.	12°		13°		14°		15°	
	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.
0′	95.68	20.34	94.94	21.92	94.15	23.47	93.30	25.00
2	95.65	20.39	94.91	21.97	94.12	23.52	93.27	25.05
4	95.63	20.44	94.89	22.02	94.09	23.58	93.24	25.10
6	95.61	20.50	94.86	22.08	94.07	23.63	93.21	25.15
8	95.58	20.55	94.84	22.13	94.04	23.68	93.18	25.20
10	95.56	20.60	94.81	22.18	94.01	23.73	93.16	25.25
12	95.53	20.66	94.79	22.23	93.98	23.78	93.13	25.30
14	95.51	20.71	94.76	22.28	93.95	23.83	93.10	25.35
16	95.49	20.76	94.73	22.34	93.93	23.88	93.07	25.40
18	95.46	20.81	94.71	22.39	93.90	23.93	93.04	25.45
20	95.44	20.87	94.68	22.44	93.87	23.99	93.01	25.50
22	95.41	20.92	94.66	22.49	93.84	24.04	92.98	25.55
24	95.39	20.97	94.63	22.54	93.81	24.09	92.95	25.60
26	95.36	21.03	94.60	22.60	93.79	24.14	92.92	25.65
28	95.34	21.08	94.58	22.65	93.76	24.19	92.89	25.70
30	95.32	21.13	94.55	22.70	93.73	24.24	92.86	25.75
32	95.29	21.18	94.52	22.75	93.70	24.29	92.83	25.80
34	95.27	21.24	94.50	22.80	93.67	24.34	92.80	25.85
36	95.24	21.29	94.47	22.85	93.65	24.39	92.77	25.90
38	95.22	21.34	94.44	22.91	93.62	24.44	92.74	25.95
40	95.19	21.39	94.42	22.96	93.59	24.49	92.71	26.00
42	95.17	21.45	94.39	23.01	93.56	24.55	92.68	26.05
44	95.14	21.50	94.36	23.06	93.53	24.60	92.65	26.10
46	95.12	21.55	94.34	23.11	93.50	24.65	92.62	26.15
48	95.09	21.60	94.31	23.16	93.47	24.70	92.59	26.20
50	95.07	21.66	94.28	23.22	93.45	24.75	92.56	26.25
52	95.04	21.71	94.26	23.27	93.42	24.80	92.53	26.30
54	95.02	21.76	94.23	23.32	93.39	24.85	92.49	26.35
56	94.99	21.81	94.20	23.37	93.36	24.90	92.46	26.40
58	94.97	21.87	94.17	23.42	93.33	24.95	92.43	26.45
60	94.94	21.92	94.15	23.47	93.30	25.00	92.40	26.50
$c = 0.75$	0.73	0.16	0.73	0.17	0.73	0.19	0.72	0.20
$c = 1.00$	0.98	0.22	0.97	0.23	0.97	0.25	0.96	0.27
$c = 1.25$	1.22	0.27	1.21	0.29	1.21	0.31	1.20	0.34

TABLE XVI — *Continued*

STADIA TABLES

M.	16°		17°		18°		19°	
	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.
0′	92.40	26.50	91.45	27.96	90.45	29.39	89.40	30.78
2	92.37	26.55	91.42	28.01	90.42	29.44	89.36	30.83
4	92.34	26.59	91.39	28.06	90.38	29.48	89.32	30.87
6	92.31	26.64	91.35	28.10	90.35	29.53	89.29	30.92
8	92.28	26.69	91.32	28.15	90.31	29.58	89.26	30.97
10	92.25	26.74	91.29	28.20	90.28	29.62	89.22	31.01
12	92.22	26.79	91.26	28.25	90.24	29.67	89.18	31.06
14	92.19	26.84	91.22	28.30	90.21	29.72	89.15	31.10
16	92.15	26.89	91.19	28.34	90.18	29.76	89.11	31.15
18	92.12	26.94	91.16	28.39	90.14	29.81	89.08	31.19
20	92.09	26.99	91.12	28.44	90.11	29.86	89.04	31.24
22	92.06	27.04	91.09	28.49	90.07	29.90	89.00	31.28
24	92.03	27.09	91.06	28.54	90.04	29.95	88.96	31.33
26	92.00	27.13	91.02	28.58	90.00	30.00	88.93	31.38
28	91.97	27.18	90.99	28.63	89.97	30.04	88.89	31.42
30	91.93	27.23	90.96	28.68	89.93	30.09	88.86	31.47
32	91.90	27.28	90.92	28.73	89.90	30.14	88.82	31.51
34	91.87	27.33	90.89	28.77	89.86	30.19	88.78	31.56
36	91.84	27.38	90.86	28.82	89.83	30.23	88.75	31.60
38	91.81	27.43	90.82	28.87	89.79	30.28	88.71	31.65
40	91.77	27.48	90.79	28.92	89.76	30.32	88.67	31.69
42	91.74	27.52	90.76	28.96	89.72	30.37	88.64	31.74
44	91.71	27.57	90.72	29.01	89.69	30.41	88.60	31.78
46	91.68	27.62	90.69	29.06	89.65	30.46	88.56	31.83
48	91.65	27.67	90.66	29.11	89.61	30.51	88.53	31.87
50	91.61	27.72	90.62	29.15	89.58	30.55	88.49	31.92
52	91.58	27.77	90.59	29.20	89.54	30.60	88.45	31.96
54	91.55	27.81	90.55	29.25	89.51	30.65	88.41	32.01
56	91.52	27.86	90.52	29.30	89.47	30.69	88.38	32.05
58	91.48	27.91	90.48	29.34	89.44	30.74	88.34	32.09
60	91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14
$c = 0.75$	0.72	0.21	0.72	0.23	0.71	0.24	0.71	0.25
$c = 1.00$	0.96	0.28	0.95	0.30	0.95	0.32	0.94	0.33
$c = 1.25$	1.20	0.36	1.19	0.38	1.19	0.40	1.18	0.42

TABLE XVI — *Continued*

STADIA TABLES

M.	20°		21°		22°		23°	
	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.
0'	88.30	32.14	87.16	33.46	85.97	34.73	84.73	35.97
2	88.26	32.18	87.12	33.50	85.93	34.77	84.69	36.01
4	88.23	32.23	87.08	33.54	85.89	34.82	84.65	36.05
6	88.19	32.27	87.04	33.59	85.85	34.86	84.61	36.09
8	88.15	32.32	87.00	33.63	85.80	34.90	84.57	36.13
10	88.11	32.36	86.96	33.67	85.76	34.94	84.52	36.17
12	88.08	32.41	86.92	33.72	85.72	34.98	84.48	36.21
14	88.04	32.45	86.88	33.76	85.68	35.02	84.44	36.25
16	88.00	32.49	86.84	33.80	85.64	35.07	84.40	36.29
18	87.96	32.54	86.80	33.84	85.60	35.11	84.35	36.33
20	87.93	32.58	86.77	33.89	85.56	35.15	84.31	36.37
22	87.89	32.63	86.73	33.93	85.52	35.19	84.27	36.41
24	87.85	32.67	86.69	33.97	85.48	35.23	84.23	36.45
26	87.81	32.72	86.65	34.01	85.44	35.27	84.18	36.49
28	87.77	32.76	86.61	34.06	85.40	35.31	84.14	36.53
30	87.74	32.80	86.57	34.10	85.36	35.36	84.10	36.57
32	87.70	32.85	86.53	34.14	85.31	35.40	84.06	36.61
34	87.66	32.89	86.49	34.18	85.27	35.44	84.01	36.65
36	87.62	32.93	86.45	34.23	85.23	35.48	83.97	36.69
38	87.58	32.98	86.41	34.27	85.19	35.52	83.93	36.73
40	87.54	33.02	86.37	34.31	85.15	35.56	83.89	36.77
42	87.51	33.07	86.33	34.35	85.11	35.60	83.84	36.80
44	87.47	33.11	86.29	34.40	85.07	35.64	83.80	36.84
46	87.43	33.15	86.25	34.44	85.02	35.68	83.76	36.88
48	87.39	33.20	86.21	34.48	84.98	35.72	83.72	36.92
50	87.35	33.24	86.17	34.52	84.94	35.76	83.67	37.96
52	87.31	33.28	86.13	34.57	84.90	35.80	83.63	37.00
54	87.27	33.33	86.09	34.61	84.86	35.85	83.59	37.04
56	87.24	33.37	86.05	34.65	84.82	35.89	83.54	37.08
58	87.20	33.41	86.01	34.69	84.77	35.93	83.50	37.12
60	87.16	33.46	85.97	34.73	84.73	35.97	83.46	37.16
$c = 0.75$	0.70	0.26	0.70	0.27	0.69	0.29	0.69	0.30
$c = 1.00$	0.94	0.35	0.93	0.37	0.92	0.38	0.92	0.40
$c = 1.25$	1.17	0.44	1.16	0.46	1.15	0.48	1.15	0.50

TABLE XVI—*Continued*

STADIA TABLES

M.	24°		25°		26°		27°	
	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.
0′	83.46	37.16	82.14	38.30	80.78	39.40	79.39	40.45
2	83.41	37.20	82.09	38.34	80.74	39.44	79.34	40.49
4	83.37	37.23	82.05	38.38	80.69	39.47	79.30	40.52
6	83.33	37.27	82.01	38.41	80.65	39.51	79.25	40.55
8	83.28	37.31	81.96	38.45	80.60	39.54	79.20	40.59
10	83.24	37.35	81.92	38.49	80.55	39.58	79.15	40.62
12	83.20	37.39	81.87	38.53	80.51	39.61	79.11	40.66
14	83.15	37.43	81.83	38.56	80.46	39.65	79.06	40.69
16	83.11	37.47	81.78	38.60	80.41	39.69	79.01	40.72
18	83.07	37.51	81.74	38.64	80.37	39.72	78.96	40.76
20	83.02	37.54	81.69	38.67	80.32	39.76	78.92	40.79
22	82.98	37.58	81.65	38.71	80.28	39.79	78.87	40.82
24	82.93	37.62	81.60	38.75	80.23	39.83	78.82	40.86
26	82.89	37.66	81.56	38.78	80.18	39.86	78.77	40.89
28	82.85	37.70	81.51	38.82	80.14	39.90	78.73	40.92
30	82.80	37.74	81.47	38.86	80.09	39.93	78.68	40.96
32	82.76	37.77	81.42	38.89	80.04	39.97	78.63	40.99
34	82.72	37.81	81.38	38.93	80.00	40.00	78.58	41.02
36	82.67	37.85	81.33	38.97	79.95	40.04	78.54	41.06
38	82.63	37.89	81.28	39.00	79.90	40.07	78.49	41.09
40	82.58	37.93	81.24	39.04	79.86	40.11	78.44	41.12
42	82.54	37.96	81.19	39.08	79.81	40.14	78.39	41.16
44	82.49	38.00	81.15	39.11	79.76	40.18	78.34	41.19
46	82.45	38.04	81.10	39.15	79.72	40.21	78.30	41.22
48	82.41	38.08	81.06	39.18	79.67	40.24	78.25	41.26
50	82.36	38.11	81.01	39.22	79.62	40.28	78.20	41.29
52	82.32	38.15	80.97	39.26	79.58	40.31	78.15	41.32
54	82.27	38.19	80.92	39.29	79.53	40.35	78.10	41.35
56	82.23	38.23	80.87	39.33	79.48	40.38	78.06	41.39
58	82.18	38.26	80.83	39.36	79.44	40.42	78.01	41.42
60	82.14	38.30	80.78	39.40	79.39	40.45	77.96	41.45
$c = 0.75$	0.68	0.31	0.68	0.32	0.67	0.33	0.66	0.35
$c = 1.00$	0.91	0.41	0.90	0.43	0.89	0.45	0.89	0.46
$c = 1.25$	1.14	0.52	1.13	0.54	1.12	0.56	1.11	0.58

TABLE XVI — *Concluded*

Stadia Tables

M.	28°		29°		30°	
	hor. dist.	diff. elev.	hor. dist.	diff. elev.	hor. dist.	diff. elev.
0′	77.96	41.45	76.50	42.40	75.00	43.30
2	77.91	41.48	76.45	42.43	74.95	43.33
4	77.86	41.52	76.40	42.46	74.90	43.36
6	77.81	41.55	76.35	42.49	74.85	43.39
8	77.77	41.58	76.30	42.53	74.80	43.42
10	77.72	41.61	76.25	42.56	74.75	43.45
12	77.67	41.65	76.20	42.59	74.70	43.47
14	77.62	41.68	76.15	42.62	74.65	43.50
16	77.57	41.71	76.10	42.65	74.60	43.53
18	77.52	41.74	76.05	42.68	74.55	43.56
20	77.48	41.77	76.00	42.71	74.49	43.59
22	77.42	41.81	75.95	42.74	74.44	43.62
24	77.38	41.84	75.90	42.77	74.39	43.65
26	77.33	41.87	75.85	42.80	74.34	43.67
28	77.28	41.90	75.80	42.83	74.29	43.70
30	77.23	41.93	75.75	42.86	74.24	43.73
32	77.18	41.97	75.70	42.89	74.19	43.76
34	77.13	42.00	75.65	42.92	74.14	43.79
36	77.09	42.03	75.60	42.95	74.09	43.82
38	77.04	42.06	75.55	42.98	74.04	43.84
40	76.99	42.09	75.50	43.01	73.99	43.87
42	76.94	42.12	75.45	43.04	73.93	43.90
44	76.89	42.15	75.40	43.07	73.88	43.93
46	76.84	42.19	75.35	43.10	73.83	43.95
48	76.79	42.22	75.30	43.13	73.78	43.98
50	76.74	42.25	75.25	43.16	73.73	44.01
52	76.69	42.28	75.20	43.18	73.68	44.04
54	76.64	42.31	75.15	43.21	73.63	44.07
56	76.59	42.34	75.10	43.24	73.58	44.09
58	76.55	42.37	75.05	43.27	73.52	44.12
60	76.50	42.40	75.00	43.30	73.47	44.15
$c = 0.75$	0.66	0.36	0.65	0.37	0.65	0.38
$c = 1.00$	0.88	0.48	0.87	0.49	0.86	0.51
$c = 1.25$	1.10	0.60	1.09	0.62	1.08	0.64

TABLE XVII

LOGARITHMS OF NUMBERS

FROM 1 TO 10,000.

N.	0	1	2	3	4	5	6	7	8	9	D.
100	00 0000	00 0434	00 0868	00 1301	00 1734	00 2166	00 2598	00 3029	00 3461	00 3891	432
101	4321	4751	5181	5609	6038	6466	6894	7321	7748	8174	428
102	8600	9026	9451	9876	01 0300	01 0724	01 1147	01 1570	01 1993	01 2415	424
103	01 2837	01 3259	01 3680	01 4100	4521	4940	5360	5779	6197	6616	420
104	7033	7451	7868	8284	8700	9116	9532	9947	02 0361	02 0775	416
105	02 1189	02 1603	02 2016	02 2428	02 2841	02 3252	02 3664	02 4075	02 4486	02 4896	412
106	5306	5715	6125	6533	6942	7350	7757	8164	8571	8978	408
107	9384	9789	03 0195	03 0600	03 1004	03 1408	03 1812	03 2216	03 2619	03 3021	404
108	03 3424	03 3826	4227	4628	5029	5430	5830	6230	6629	7028	400
109	7426	7825	8223	8620	9017	9414	9811	04 0207	04 0602	04 0998	397
110	04 1393	04 1787	04 2182	04 2576	04 2969	04 3362	04 3755	04 4148	04 4540	04 4932	393
111	5323	5714	6105	6495	6885	7275	7664	8053	8442	8830	390
112	9218	9606	9993	05 0380	05 0766	05 1153	05 1538	05 1924	05 2309	05 2694	386
113	05 3078	05 3463	05 3846	4230	4613	4996	5378	5760	6142	6524	383
114	6905	7286	7666	8046	8426	8805	9185	9563	9942	06 0320	379
115	06 0698	06 1075	06 1452	06 1829	06 2206	06 2582	06 2958	06 3333	06 3709	06 4083	376
116	4458	4832	5206	5580	5953	6326	6699	7071	7443	7815	373
117	8186	8557	8928	9298	9668	07 0038	07 0407	07 0776	07 1145	07 1514	370
118	07 1882	07 2250	07 2617	07 2985	07 3352	3718	4085	4451	4816	5182	366
119	5547	5912	6276	6640	7004	7368	7731	8094	8457	8819	363
120	07 9181	07 9543	07 9904	08 0266	08 0626	08 0987	08 1347	08 1707	08 2067	08 2426	360
121	08 2785	08 3144	08 3503	3861	4219	4576	4934	5291	5647	6004	357
122	6360	6716	7071	7426	7781	8136	8490	8845	9198	9552	355
123	9905	09 0258	09 0611	09 0963	09 1315	09 1667	09 2018	09 2370	09 2721	09 3071	352
124	09 3422	3772	4122	4471	4820	5169	5518	5866	6215	6562	349
125	09 6910	09 7257	09 7604	09 7951	09 8298	09 8644	09 8990	09 9335	09 9681	10 0026	346
126	10 0371	10 0715	10 1059	10 1403	10 1747	10 2091	10 2434	10 2777	10 3119	3462	343
127	3804	4146	4487	4828	5169	5510	5851	6191	6531	6871	341
128	7210	7549	7888	8227	8565	8903	9241	9579	9916	11 0253	338
129	11 0590	11 0926	11 1263	11 1599	11 1934	11 2270	11 2605	11 2940	11 3275	3609	335
130	11 3943	11 4277	11 4611	11 4944	11 5278	11 5611	11 5943	11 6276	11 6608	11 6940	333
131	7271	7603	7934	8265	8595	8926	9256	9586	9915	12 0245	330
132	12 0574	12 0903	12 1231	12 1560	12 1888	12 2216	12 2544	12 2871	12 3198	3525	328
133	3852	4178	4504	4830	5156	5481	5806	6131	6456	6781	325
134	7105	7429	7753	8076	8399	8722	9045	9368	9690	13 0012	323
135	13 0334	13 0655	13 0977	13 1298	13 1619	13 1939	13 2260	13 2580	13 2900	13 3219	321
136	3539	3858	4177	4496	4814	5133	5451	5769	6086	6403	318
137	6721	7037	7354	7671	7987	8303	8618	8934	9249	9564	316
138	9879	14 0194	14 0508	14 0822	14 1136	14 1450	14 1763	14 2076	14 2389	14 2702	314
139	14 3015	3327	3639	3951	4263	4574	4885	5196	5507	5818	311
140	14 6128	14 6438	14 6748	14 7058	14 7367	14 7676	14 7985	14 8294	14 8603	14 8911	309
141	9219	9527	9835	15 0142	15 0449	15 0756	15 1063	15 1370	15 1676	15 1982	307
142	15 2288	15 2594	15 2900	3205	3510	3815	4120	4424	4728	5032	305
143	5336	5640	5943	6246	6549	6852	7154	7457	7759	8061	303
144	8362	8664	8965	9266	9567	9868	16 0168	16 0469	16 0769	16 1068	301
145	16 1368	16 1667	16 1967	16 2266	16 2564	16 2863	16 3161	16 3460	16 3758	16 4055	299
146	4353	4650	4947	5244	5541	5838	6134	6430	6726	7022	297
147	7317	7613	7908	8203	8497	8792	9086	9380	9674	9968	295
148	17 0262	17 0555	17 0848	17 1141	17 1434	17 1726	17 2019	17 2311	17 2603	17 2895	293
149	3186	3478	3769	4060	4351	4641	4932	5222	5512	5802	291
150	17 6091	17 6381	17 6670	17 6959	17 7248	17 7536	17 7825	17 8113	17 8401	17 8689	289
151	8977	9264	9552	9839	18 0126	18 0413	18 0699	18 0986	18 1272	18 1558	287
152	18 1844	18 2129	18 2415	18 2700	2985	3270	3555	3839	4123	4407	285
153	4691	4975	5259	5542	5825	6108	6391	6674	6956	7239	283
154	7521	7803	8084	8366	8647	8928	9209	9490	9771	19 0051	281
155	19 0332	19 0612	19 0892	19 1171	19 1451	19 1730	19 2010	19 2289	19 2567	19 2846	279
156	3125	3403	3681	3959	4237	4514	4792	5069	5346	5623	278
157	5900	6176	6453	6729	7005	7281	7556	7832	8107	8382	276
158	8657	8932	9206	9481	9755	20 0029	20 0303	20 0577	20 0850	20 1124	274
159	20 1397	20 1670	20 1943	20 2216	20 2488	2761	3033	3305	3577	3848	272
N.	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
160	20 4120	20 4391	20 4663	20 4934	20 5204	20 5475	20 5746	20 6016	20 6286	20 6556	271
161	6826	7096	7365	7634	7904	8173	8441	8710	8979	9247	269
162	9515	9783	21 0051	21 0319	21 0586	21 0853	21 1121	21 1388	21 1654	21 1921	267
163	21 2188	21 2454	2720	2986	3252	3518	3783	4049	4314	4579	266
164	4844	5109	5373	5638	5902	6166	6430	6694	6957	7221	264
165	21 7484	21 7747	21 8010	21 8273	21 8536	21 8798	21 9060	21 9323	21 9585	21 9846	262
166	22 0108	22 0370	22 0631	22 0892	22 1153	22 1414	22 1675	22 1936	22 2196	22 2456	261
167	2716	2976	3236	3496	3755	4015	4274	4533	4792	5051	259
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181	7679	7918	8158	8398	8637	8877	9116	9355	9594	9833	239
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187	27 1842	27 2074	27 2306	2538	2770	3001	3233	3464	3696	3927	232
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222	6353	6549	6744	6939	7135	7330	7525	7720	7915	8110	195
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225	35 2183	35 2375	35 2568	35 2761	35 2954	35 3147	35 3339	35 3532	35 3724	35 3916	193
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233	7356	7542	7729	7915	8101	8287	8473	8659	8845	9030	186
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235	37 1068	37 1253	37 1437	37 1622	37 1806	37 1991	37 2175	37 2360	37 2544	37 2728	184
236	2912	3096	3280	3464	3647	3831	4015	4198	4382	4565	184
237	4748	4932	5115	5298	5481	5664	5846	6029	6212	6394	183
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244	7390	7568	7746	7923	8101	8279	8456	8634	8811	8989	178
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246	39 0935	39 1112	39 1288	39 1464	39 1641	1817	1993	2169	2345	2521	176
247	2697	2873	3048	3224	3400	3575	3751	3926	4101	4277	176
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251	9674	9847	40 0020	40 0192	40 0365	40 0538	40 0711	40 0883	40 1056	40 1228	173
252	40 1401	40 1573	1745	1917	2089	2261	2433	2605	2777	2949	172
253	3121	3292	3464	3635	3807	3978	4149	4320	4492	4663	171
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265	42 3246	42 3410	42 3574	42 3737	42 3901	42 4065	42 4228	42 4392	42 4555	42 4718	164
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281	8706	8861	9015	9170	9324	9478	9633	9787	9941	45 0095	154
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283	1786	1940	2093	2247	2400	2553	2706	2859	3012	3165	153
284	3318	3471	3624	3777	3930	4082	4235	4387	4540	4692	153
285	45 4845	45 4997	45 5150	45 5302	45 5454	45 5606	45 5758	45 5910	45 6062	45 6214	152
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296	47 1292	47 1438	1585	1732	1878	2025	2171	2318	2464	2610	146
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303	1443	1586	1729	1872	2016	2159	2302	2445	2588	2731	143
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310	49 1362	49 1502	49 1642	49 1782	49 1922	49 2062	49 2201	49 2341	49 2481	49 2621	140
311	2760	2900	3040	3179	3319	3458	3597	3737	3876	4015	139
312	4155	4294	4433	4572	4711	4850	4989	5128	5267	5406	139
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350	54 4068	54 4192	54 4316	54 4440	54 4564	54 4688	54 4812	54 4936	54 5060	54 5183	124
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363	9907	56 0026	56 0146	56 0265	56 0385	56 0504	56 0624	56 0743	56 0863	56 0982	119
364	56 1101	1221	1340	1459	1578	1698	1817	1936	2055	2174	119
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366	3481	3600	3718	3837	3955	4074	4192	4311	4429	4548	119
367	4666	4784	4903	5021	5139	5257	5376	5494	5612	5730	118
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371	9374	9491	9608	9725	9842	9959	57 0076	57 0193	57 0309	57 0426	117
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373	1709	1825	1942	2058	2174	2291	2407	2523	2639	2755	116
374	2872	2988	3104	3220	3336	3452	3568	3684	3800	3915	116
375	57 4031	57 4147	57 4263	57 4379	57 4494	57 4610	57 4726	57 4841	57 4957	57 5072	116
376	5188	5303	5419	5534	5650	5765	5880	5996	6111	6226	115
377	6341	6457	6572	6687	6802	6917	7032	7147	7262	7377	115
378	7492	7607	7722	7836	7951	8066	8181	8295	8410	8525	115
379	8639	8754	8868	8983	9097	9212	9326	9441	9555	9669	114
380	57 9784	57 9898	58 0012	58 0126	58 0241	58 0355	58 0469	58 0583	58 0697	58 0811	114
381	58 0925	58 1039	1153	1267	1381	1495	1608	1722	1836	1950	114
382	2063	2177	2291	2404	2518	2631	2745	2858	2972	3085	114
383	3199	3312	3426	3539	3652	3765	3879	3992	4105	4218	113
384	4331	4444	4557	4670	4783	4896	5009	5122	5235	5348	113
385	58 5461	58 5574	58 5686	58 5799	58 5912	58 6024	58 6137	58 6250	58 6362	58 6475	113
386	6587	6700	6812	6925	7037	7149	7262	7374	7486	7599	112
387	7711	7823	7935	8047	8160	8272	8384	8496	8608	8720	112
388	8832	8944	9056	9167	9279	9391	9503	9615	9726	9838	112
389	9950	59 0061	59 0173	59 0284	59 0396	59 0507	59 0619	59 0730	59 0842	59 0953	112
390	59 1065	59 1176	59 1287	59 1399	59 1510	59 1621	59 1732	59 1843	59 1955	59 2066	111
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394	5496	5606	5717	5827	5937	6047	6157	6267	6377	6487	110
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397	8791	8900	9009	9119	9228	9337	9446	9556	9665	9774	109
398	9883	9992	60 0101	60 0210	60 0319	60 0428	60 0537	60 0646	60 0755	60 0864	109
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402	4226	4334	4442	4550	4658	4766	4874	4982	5089	5197	108
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415	61 8048	61 8153	61 8257	61 8362	61 8466	61 8571	61 8676	61 8780	61 8884	61 8989	105
416	9093	9198	9302	9406	9511	9615	9719	9824	9928	62 0032	104
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418	1176	1280	1384	1488	1592	1695	1799	1903	2007	2110	104
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420	62 3249	62 3353	62 3456	62 3559	62 3663	62 3766	62 3869	62 3973	62 4076	62 4179	103
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431	4477	4578	4679	4779	4880	4981	5081	5182	5283	5383	101
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449	2246	2343	2440	2536	2633	2730	2826	2923	3019	3116	97
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452	5138	5235	5331	5427	5523	5619	5715	5810	5906	6002	96
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456	8965	9060	9155	9250	9346	9441	9536	9631	9726	9821	95
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462	4642	4736	4830	4924	5018	5112	5206	5299	5393	5487	94
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464	6518	6612	6705	6799	6892	6986	7079	7173	7266	7360	94
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466	8386	8479	8572	8665	8759	8852	8945	9038	9131	9224	93
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470	67 2098	67 2190	67 2283	67 2375	67 2467	67 2560	67 2652	67 2744	67 2836	67 2929	92
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474	5778	5870	5962	6053	6145	6236	6328	6419	6511	6602	92
475	67 6694	67 6785	67 6876	67 6968	67 7059	67 7151	67 7242	67 7333	67 7424	67 7516	91
476	7607	7698	7789	7881	7972	8063	8154	8245	8336	8427	91
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480	68 1241	68 1332	68 1422	68 1513	68 1603	68 1693	68 1784	68 1874	68 1964	68 2055	90
481	2145	2235	2326	2416	2506	2596	2686	2777	2867	2957	90
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484	4845	4935	5025	5114	5204	5294	5383	5473	5563	5652	90
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486	6636	6726	6815	6904	6994	7083	7172	7261	7351	7440	89
487	7529	7618	7707	7796	7886	7975	8064	8153	8242	8331	89
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489	9309	9398	9486	9575	9664	9753	9841	9930	69 0019	69 0107	89
490	69 0196	69 0285	69 0373	69 0462	69 0550	69 0639	69 0728	69 0816	69 0905	69 0993	89
491	1081	1170	1258	1347	1435	1524	1612	1700	1789	1877	88
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493	2847	2935	3023	3111	3199	3287	3375	3463	3551	3639	88
494	3727	3815	3903	3991	4078	4166	4254	4342	4430	4517	88
495	69 4605	69 4693	69 4781	69 4868	69 4956	69 5044	69 5131	69 5219	69 5307	69 5394	88
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514	0963	1048	1132	1217	1301	1385	1470	1554	1639	1723	84
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517	3491	3575	3659	3742	3826	3910	3994	4078	4162	4246	84
518	4330	4414	4497	4581	4665	4749	4833	4916	5000	5084	84
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522	7671	7754	7837	7920	8003	8086	8169	8253	8336	8419	83
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524	9331	9414	9497	9580	9663	9745	9828	9911	9994	72 0077	83
525	72 0159	72 0242	72 0325	72 0407	72 0490	72 0573	72 0655	72 0738	72 0821	72 0903	83
526	0986	1068	1151	1233	1316	1398	1481	1563	1646	1728	82
527	1811	1893	1975	2058	2140	2222	2305	2387	2469	2552	82
528	2634	2716	2798	2881	2963	3045	3127	3209	3291	3374	82
529	3456	3538	3620	3702	3784	3866	3948	4030	4112	4194	82
530	72 4276	72 4358	72 4440	72 4522	72 4604	72 4685	72 4767	72 4849	72 4931	72 5013	82
531	5095	5176	5258	5340	5422	5503	5585	5667	5748	5830	82
532	5912	5993	6075	6156	6238	6320	6401	6483	6564	6646	82
533	6727	6809	6890	6972	7053	7134	7216	7297	7379	7460	81
534	7541	7623	7704	7785	7866	7948	8029	8110	8191	8273	81
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536	9165	9246	9327	9408	9489	9570	9651	9732	9813	9893	81
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540	73 2394	73 2474	73 2555	73 2635	73 2715	73 2796	73 2876	73 2956	73 3037	73 3117	80
541	3197	3278	3358	3438	3518	3598	3679	3759	3839	3919	80
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543	4800	4880	4960	5040	5120	5200	5279	5359	5439	5519	80
544	5599	5679	5759	5838	5918	5998	6078	6157	6237	6317	80
545	73 6397	73 6476	73 6556	73 6635	73 6715	73 6795	73 6874	73 6954	73 7034	73 7113	80
546	7193	7272	7352	7431	7511	7590	7670	7749	7829	7908	79
547	7987	8067	8146	8225	8305	8384	8463	8543	8622	8701	79
548	8781	8860	8939	9018	9097	9177	9256	9335	9414	9493	79
549	9572	9651	9731	9810	9889	9968	74 0047	74 0126	74 0205	74 0284	79
550	74 0363	74 0442	74 0521	74 0600	74 0678	74 0757	74 0836	74 0915	74 0994	74 1073	79
551	1152	1230	1309	1388	1467	1546	1624	1703	1782	1860	79
552	1939	2018	2096	2175	2254	2332	2411	2489	2568	2647	79
553	2725	2804	2882	2961	3039	3118	3196	3275	3353	3431	78
554	3510	3588	3667	3745	3823	3902	3980	4058	4136	4215	78
555	74 4293	74 4371	74 4449	74 4528	74 4606	74 4684	74 4762	74 4840	74 4919	74 4997	78
556	5075	5153	5231	5309	5387	5465	5543	5621	5699	5777	78
557	5855	5933	6011	6089	6167	6245	6323	6401	6479	6556	78
558	6634	6712	6790	6868	6945	7023	7101	7179	7256	7334	78
559	7412	7489	7567	7645	7722	7800	7878	7955	8033	8110	78
560	74 8188	74 8266	74 8343	74 8421	74 8498	74 8576	74 8653	74 8731	74 8808	74 8885	77
561	8963	9040	9118	9195	9272	9350	9427	9504	9582	9659	77
562	9736	9814	9891	9968	75 0045	75 0123	75 0200	75 0277	75 0354	75 0431	77
563	75 0508	75 0586	75 0663	75 0740	0817	0894	0971	1048	1125	1202	77
564	1279	1356	1433	1510	1587	1664	1741	1818	1895	1972	77
565	75 2048	75 2125	75 2202	75 2279	75 2356	75 2433	75 2509	75 2586	75 2663	75 2740	77
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571	6636	6712	6788	6864	6940	7016	7092	7168	7244	7320	76
572	7396	7472	7548	7624	7700	7775	7851	7927	8003	8079	76
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574	8912	8988	9063	9139	9214	9290	9366	9441	9517	9592	76
575	75 9668	75 9743	75 9819	75 9894	75 9970	76 0045	76 0121	76 0196	76 0272	76 0347	75
576	76 0422	76 0498	76 0573	76 0649	76 0724	0799	0875	0950	1025	1101	75
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578	1928	2003	2078	2153	2228	2303	2378	2453	2529	2604	75
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581	4176	4251	4326	4400	4475	4550	4624	4699	4774	4848	75
582	4923	4998	5072	5147	5221	5296	5370	5445	5520	5594	75
583	5669	5743	5818	5892	5966	6041	6115	6190	6264	6338	74
584	6413	6487	6562	6636	6710	6785	6859	6933	7007	7082	74
585	76 7156	76 7230	76 7304	76 7379	76 7453	76 7527	76 7601	76 7675	76 7749	76 7823	74
586	7898	7972	8046	8120	8194	8268	8342	8416	8490	8564	74
587	8638	8712	8786	8860	8934	9008	9082	9156	9230	9303	74
588	9377	9451	9525	9599	9673	9746	9820	9894	9968	77 0042	74
589	77 0115	77 0189	77 0263	77 0336	77 0410	77 0484	77 0557	77 0631	77 0705	0778	74
590	77 0852	77 0926	77 0999	77 1073	77 1146	77 1220	77 1293	77 1367	77 1440	77 1514	74
591	1587	1661	1734	1808	1881	1955	2028	2102	2175	2248	73
592	2322	2395	2468	2542	2615	2688	2762	2835	2908	2981	73
593	3055	3128	3201	3274	3348	3421	3494	3567	3640	3713	73
594	3786	3860	3933	4006	4079	4152	4225	4298	4371	4444	73
595	77 4517	77 4590	77 4663	77 4736	77 4809	77 4882	77 4955	77 5028	77 5100	77 5173	73
596	5246	5319	5392	5465	5538	5610	5683	5756	5829	5902	73
597	5974	6047	6120	6193	6265	6338	6411	6483	6556	6629	73
598	6701	6774	6846	6919	6992	7064	7137	7209	7282	7354	73
599	7427	7499	7572	7644	7717	7789	7862	7934	8006	8079	72
600	77 8151	77 8224	77 8296	77 8368	77 8441	77 8513	77 8585	77 8658	77 8730	77 8802	72
601	8874	8947	9019	9091	9163	9236	9308	9380	9452	9524	72
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603	78 0317	78 0389	78 0461	78 0533	78 0605	78 0677	0749	0821	0893	0965	72
604	1037	1109	1181	1253	1324	1396	1468	1540	1612	1684	72
605	78 1755	78 1827	78 1899	78 1971	78 2042	78 2114	78 2186	78 2258	78 2329	78 2401	72
606	2473	2544	2616	2688	2759	2831	2902	2974	3046	3117	72
607	3189	3260	3332	3403	3475	3546	3618	3689	3761	3832	71
608	3904	3975	4046	4118	4189	4261	4332	4403	4475	4546	71
609	4617	4689	4760	4831	4902	4974	5045	5116	5187	5259	71
610	78 5330	78 5401	78 5472	78 5543	78 5615	78 5686	78 5757	78 5828	78 5899	78 5970	71
611	6041	6112	6183	6254	6325	6396	6467	6538	6609	6680	71
612	6751	6822	6893	6964	7035	7106	7177	7248	7319	7390	71
613	7460	7531	7602	7673	7744	7815	7885	7956	8027	8098	71
614	8168	8239	8310	8381	8451	8522	8593	8663	8734	8804	71
615	78 8875	78 8946	78 9016	78 9087	78 9157	78 9228	78 9299	78 9369	78 9440	78 9510	71
616	9581	9651	9722	9792	9863	9933	79 0004	79 0074	79 0144	79 0215	70
617	79 0285	79 0356	79 0426	79 0496	79 0567	79 0637	0707	0778	0848	0918	70
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624	5185	5254	5324	5393	5463	5532	5602	5672	5741	5811	70
625	79 5880	79 5949	79 6019	79 6088	79 6158	79 6227	79 6297	79 6366	79 6436	79 6505	69
626	6574	6644	6713	6782	6852	6921	6990	7060	7129	7198	69
627	7268	7337	7406	7475	7545	7614	7683	7752	7821	7890	69
628	7960	8029	8098	8167	8236	8305	8374	8443	8513	8582	69
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631	80 0029	80 0098	80 0167	80 0236	80 0305	80 0373	80 0442	80 0511	80 0580	80 0648	69
632	0717	0786	0854	0923	0992	1061	1129	1198	1266	1335	69
633	1404	1472	1541	1609	1678	1747	1815	1884	1952	2021	69
634	2089	2158	2226	2295	2363	2432	2500	2568	2637	2705	68
635	80 2774	80 2842	80 2910	80 2979	80 3047	80 3116	80 3184	80 3252	80 3321	80 3389	68
636	3457	3525	3594	3662	3730	3798	3867	3935	4003	4071	68
637	4139	4208	4276	4344	4412	4480	4548	4616	4685	4753	68
638	4821	4889	4957	5025	5093	5161	5229	5297	5365	5433	68
639	5501	5569	5637	5705	5773	5841	5908	5976	6044	6112	68
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641	6858	6926	6994	7061	7129	7197	7264	7332	7400	7467	68
642	7535	7603	7670	7738	7806	7873	7941	8008	8076	8143	68
643	8211	8279	8346	8414	8481	8549	8616	8684	8751	8818	67
644	8886	8953	9021	9088	9156	9223	9290	9358	9425	9492	67
645	80 9560	80 9627	80 9694	80 9762	80 9829	80 9896	80 9964	81 0031	81 0098	81 0165	67
646	81 0233	81 0300	81 0367	81 0434	81 0501	81 0569	81 0636	0703	0770	0837	67
647	0904	0971	1039	1106	1173	1240	1307	1374	1441	1508	67
648	1575	1642	1709	1776	1843	1910	1977	2044	2111	2178	67
649	2245	2312	2379	2445	2512	2579	2646	2713	2780	2847	67
650	81 2913	81 2980	81 3047	81 3114	81 3181	81 3247	81 3314	81 3381	81 3448	81 3514	67
651	3581	3648	3714	3781	3848	3914	3981	4048	4114	4181	67
652	4248	4314	4381	4447	4514	4581	4647	4714	4780	4847	67
653	4913	4980	5046	5113	5179	5246	5312	5378	5445	5511	66
654	5578	5644	5711	5777	5843	5910	5976	6042	6109	6175	66
655	81 6241	81 6308	81 6374	81 6440	81 6506	81 6573	81 6639	81 6705	81 6771	81 6838	66
656	6904	6970	7036	7102	7169	7235	7301	7367	7433	7499	66
657	7565	7631	7698	7764	7830	7896	7962	8028	8094	8160	66
658	8226	8292	8358	8424	8490	8556	8622	8688	8754	8820	66
659	8885	8951	9017	9083	9149	9215	9281	9346	9412	9478	66
660	81 9544	81 9610	81 9676	81 9741	81 9807	81 9873	81 9939	82 0004	82 0070	82 0136	66
661	82 0201	82 0267	82 0333	82 0399	82 0464	82 0530	82 0595	0661	0727	0792	66
662	0858	0924	0989	1055	1120	1186	1251	1317	1382	1448	66
663	1514	1579	1645	1710	1775	1841	1906	1972	2037	2103	65
664	2168	2233	2299	2364	2430	2495	2560	2626	2691	2756	65
665	82 2822	82 2887	82 2952	82 3018	82 3083	82 3148	82 3213	82 3279	82 3344	82 3409	65
666	3474	3539	3605	3670	3735	3800	3865	3930	3996	4061	65
667	4126	4191	4256	4321	4386	4451	4516	4581	4646	4711	65
668	4776	4841	4906	4971	5036	5101	5166	5231	5296	5361	65
669	5426	5491	5556	5621	5686	5751	5815	5880	5945	6010	65
670	82 6075	82 6140	82 6204	82 6269	82 6334	82 6399	82 6464	82 6528	82 6593	82 6658	65
671	6723	6787	6852	6917	6981	7046	7111	7175	7240	7305	65
672	7369	7434	7499	7563	7628	7692	7757	7821	7886	7951	65
673	8015	8080	8144	8209	8273	8338	8402	8467	8531	8595	64
674	8660	8724	8789	8853	8918	8982	9046	9111	9175	9239	64
675	82 9304	82 9368	82 9432	82 9497	82 9561	82 9625	82 9690	82 9754	82 9818	82 9882	64
676	9947	83 0011	83 0075	83 0139	83 0204	83 0268	83 0332	83 0396	83 0460	83 0525	64
677	83 0589	0653	0717	0781	0845	0909	0973	1037	1102	1166	64
678	1230	1294	1358	1422	1486	1550	1614	1678	1742	1806	64
679	1870	1934	1998	2062	2126	2189	2253	2317	2381	2445	64
680	83 2509	83 2573	83 2637	83 2700	83 2764	83 2828	83 2892	83 2956	83 3020	83 3083	64
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682	3784	3848	3912	3975	4039	4103	4166	4230	4294	4357	64
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684	5056	5120	5183	5247	5310	5373	5437	5500	5564	5627	63
685	83 5691	83 5754	83 5817	83 5881	83 5944	83 6007	83 6071	83 6134	83 6197	83 6261	63
686	6324	6387	6451	6514	6577	6641	6704	6767	6830	6894	63
687	6957	7020	7083	7146	7210	7273	7336	7399	7462	7525	63
688	7588	7652	7715	7778	7841	7904	7967	8030	8093	8156	63
689	8219	8282	8345	8408	8471	8534	8597	8660	8723	8786	63
690	83 8849	83 8912	83 8975	83 9038	83 9101	83 9164	83 9227	83 9289	83 9352	83 9415	63
691	9478	9541	9604	9667	9729	9792	9855	9918	9981	84 0043	63
692	84 0106	84 0169	84 0232	84 0294	84 0357	84 0420	84 0482	84 0545	84 0608	0671	63
693	0733	0796	0859	0921	0984	1046	1109	1172	1234	1297	63
694	1359	1422	1485	1547	1610	1672	1735	1797	1860	1922	63
695	84 1985	84 2047	84 2110	84 2172	84 2235	84 2297	84 2360	84 2422	84 2484	84 2547	62
696	2609	2672	2734	2796	2859	2921	2983	3046	3108	3170	62
697	3233	3295	3357	3420	3482	3544	3606	3669	3731	3793	62
698	3855	3918	3980	4042	4104	4166	4229	4291	4353	4415	62
699	4477	4539	4601	4664	4726	4788	4850	4912	4974	5036	62
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701	5718	5780	5842	5904	5966	6028	6090	6151	6213	6275	62
702	6337	6399	6461	6523	6585	6646	6708	6770	6832	6894	62
703	6955	7017	7079	7141	7202	7264	7326	7388	7449	7511	62
704	7573	7634	7696	7758	7819	7881	7943	8004	8066	8128	62
705	84 8189	84 8251	84 8312	84 8374	84 8435	84 8497	84 8559	84 8620	84 8682	84 8743	62
706	8805	8866	8928	8989	9051	9112	9174	9235	9297	9358	61
707	9419	9481	9542	9604	9665	9726	9788	9849	9911	9972	61
708	85 0033	85 0095	85 0156	85 0217	85 0279	85 0340	85 0401	85 0462	85 0524	85 0585	61
709	0646	0707	0769	0830	0891	0952	1014	1075	1136	1197	61
710	85 1258	85 1320	85 1381	85 1442	85 1503	85 1564	85 1625	85 1686	85 1747	85 1809	61
711	1870	1931	1992	2053	2114	2175	2236	2297	2358	2419	61
712	2480	2541	2602	2663	2724	2785	2846	2907	2968	3029	61
713	3090	3150	3211	3272	3333	3394	3455	3516	3577	3637	61
714	3698	3759	3820	3881	3941	4002	4063	4124	4185	4245	61
715	85 4306	85 4367	85 4428	85 4488	85 4549	85 4610	85 4670	85 4731	85 4792	85 4852	61
716	4913	4974	5034	5095	5156	5216	5277	5337	5398	5459	61
717	5519	5580	5640	5701	5761	5822	5882	5943	6003	6064	61
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721	7935	7995	8056	8116	8176	8236	8297	8357	8417	8477	60
722	8537	8597	8657	8718	8778	8838	8898	8958	9018	9078	60
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725	86 0338	86 0398	86 0458	86 0518	86 0578	86 0637	86 0697	86 0757	86 0817	86 0877	60
726	0937	0996	1056	1116	1176	1236	1295	1355	1415	1475	60
727	1534	1594	1654	1714	1773	1833	1893	1952	2012	2072	60
728	2131	2191	2251	2310	2370	2430	2489	2549	2608	2668	60
729	2728	2787	2847	2906	2966	3025	3085	3144	3204	3263	60
730	86 3323	86 3382	86 3442	86 3501	86 3561	86 3620	86 3680	86 3739	86 3799	86 3858	59
731	3917	3977	4036	4096	4155	4214	4274	4333	4392	4452	59
732	4511	4570	4630	4689	4748	4808	4867	4926	4985	5045	59
733	5104	5163	5222	5282	5341	5400	5459	5519	5578	5637	59
734	5696	5755	5814	5874	5933	5992	6051	6110	6169	6228	59
735	86 6287	86 6346	86 6405	86 6465	86 6524	86 6583	86 6642	86 6701	86 6760	86 6819	59
736	6878	6937	6996	7055	7114	7173	7232	7291	7350	7409	59
737	7467	7526	7585	7644	7703	7762	7821	7880	7939	7998	59
738	8056	8115	8174	8233	8292	8350	8409	8468	8527	8586	59
739	8644	8703	8762	8821	8879	8938	8997	9056	9114	9173	59
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741	9818	9877	9935	9994	87 0053	87 0111	87 0170	87 0228	87 0287	87 0345	59
742	87 0404	87 0462	87 0521	87 0579	0638	0696	0755	0813	0872	0930	58
743	0989	1047	1106	1164	1223	1281	1339	1398	1456	1515	58
744	1573	1631	1690	1748	1806	1865	1923	1981	2040	2098	58
745	87 2156	87 2215	87 2273	87 2331	87 2389	87 2448	87 2506	87 2564	87 2622	87 2681	58
746	2739	2797	2855	2913	2972	3030	3088	3146	3204	3262	58
747	3321	3379	3437	3495	3553	3611	3669	3727	3785	3844	58
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749	4482	4540	4598	4656	4714	4772	4830	4888	4945	5003	58
750	87 5061	87 5119	87 5177	87 5235	87 5293	87 5351	87 5409	87 5466	87 5524	87 5582	58
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752	6218	6276	6333	6391	6449	6507	6564	6622	6680	6737	58
753	6795	6853	6910	6968	7026	7083	7141	7199	7256	7314	58
754	7371	7429	7487	7544	7602	7659	7717	7774	7832	7889	58
755	87 7947	87 8004	87 8062	87 8119	87 8177	87 8234	87 8292	87 8349	87 8407	87 8464	57
756	8522	8579	8637	8694	8752	8809	8866	8924	8981	9039	57
757	9096	9153	9211	9268	9325	9383	9440	9497	9555	9612	57
758	9669	9726	9784	9841	9898	9956	88 0013	88 0070	88 0127	88 0185	57
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761	1385	1442	1499	1556	1613	1670	1727	1784	1841	1898	57
762	1955	2012	2069	2126	2183	2240	2297	2354	2411	2468	57
763	2525	2581	2638	2695	2752	2809	2866	2923	2980	3037	57
764	3093	3150	3207	3264	3321	3377	3434	3491	3548	3605	57
765	88 3661	88 3718	88 3775	88 3832	88 3888	88 3945	88 4002	88 4059	88 4115	88 4172	57
766	4229	4285	4342	4399	4455	4512	4569	4625	4682	4739	57
767	4795	4852	4909	4965	5022	5078	5135	5192	5248	5305	57
768	5361	5418	5474	5531	5587	5644	5700	5757	5813	5870	57
769	5926	5983	6039	6096	6152	6209	6265	6321	6378	6434	56
770	88 6491	88 6547	88 6604	88 6660	88 6716	88 6773	88 6829	88 6885	88 6942	88 6998	56
771	7054	7111	7167	7223	7280	7336	7392	7449	7505	7561	56
772	7617	7674	7730	7786	7842	7898	7955	8011	8067	8123	56
773	8179	8236	8292	8348	8404	8460	8516	8573	8629	8685	56
774	8741	8797	8853	8909	8965	9021	9077	9134	9190	9246	56
775	88 9302	88 9358	88 9414	88 9470	88 9526	88 9582	88 9638	88 9694	88 9750	88 9806	56
776	9862	9918	9974	89 0030	89 0086	89 0141	89 0197	89 0253	89 0309	89 0365	56
777	89 0421	89 0477	89 0533	0589	0645	0700	0756	0812	0868	0924	56
778	0980	1035	1091	1147	1203	1259	1314	1370	1426	1482	56
779	1537	1593	1649	1705	1760	1816	1872	1928	1983	2039	56
780	89 2095	89 2150	89 2206	89 2262	89 2317	89 2373	89 2429	89 2484	89 2540	89 2595	56
781	2651	2707	2762	2818	2873	2929	2985	3040	3096	3151	56
782	3207	3262	3318	3373	3429	3484	3540	3595	3651	3706	56
783	3762	3817	3873	3928	3984	4039	4094	4150	4205	4261	55
784	4316	4371	4427	4482	4538	4593	4648	4704	4759	4814	55
785	89 4870	89 4925	89 4980	89 5036	89 5091	89 5146	89 5201	89 5257	89 5312	89 5367	55
786	5423	5478	5533	5588	5644	5699	5754	5809	5864	5920	55
787	5975	6030	6085	6140	6195	6251	6306	6361	6416	6471	55
788	6526	6581	6636	6692	6747	6802	6857	6912	6967	7022	55
789	7077	7132	7187	7242	7297	7352	7407	7462	7517	7572	55
790	89 7627	89 7682	89 7737	89 7792	89 7847	89 7902	89 7957	89 8012	89 8067	89 8122	55
791	8176	8231	8286	8341	8396	8451	8506	8561	8615	8670	55
792	8725	8780	8835	8890	8944	8999	9054	9109	9164	9218	55
793	9273	9328	9383	9437	9492	9547	9602	9656	9711	9766	55
794	9821	9875	9930	9985	90 0039	90 0094	90 0149	90 0203	90 0258	90 0312	55
795	90 0367	90 0422	90 0476	90 0531	90 0586	90 0640	90 0695	90 0749	90 0804	90 0859	55
796	0913	0968	1022	1077	1131	1186	1240	1295	1349	1404	55
797	1458	1513	1567	1622	1676	1731	1785	1840	1894	1948	54
798	2003	2057	2112	2166	2221	2275	2329	2384	2438	2492	54
799	2547	2601	2655	2710	2764	2818	2873	2927	2981	3036	54
800	90 3090	90 3144	90 3199	90 3253	90 3307	90 3361	90 3416	90 3470	90 3524	90 3578	54
801	3633	3687	3741	3795	3849	3904	3958	4012	4066	4120	54
802	4174	4229	4283	4337	4391	4445	4499	4553	4607	4661	54
803	4716	4770	4824	4878	4932	4986	5040	5094	5148	5202	54
804	5256	5310	5364	5418	5472	5526	5580	5634	5688	5742	54
805	90 5796	90 5850	90 5904	90 5958	90 6012	90 6066	90 6119	90 6173	90 6227	90 6281	54
806	6335	6389	6443	6497	6551	6604	6658	6712	6766	6820	54
807	6874	6927	6981	7035	7089	7143	7196	7250	7304	7358	54
808	7411	7465	7519	7573	7626	7680	7734	7787	7841	7895	54
809	7949	8002	8056	8110	8163	8217	8270	8324	8378	8431	54
810	90 8485	90 8539	90 8592	90 8646	90 8699	90 8753	90 8807	90 8860	90 8914	90 8967	54
811	9021	9074	9128	9181	9235	9289	9342	9396	9449	9503	54
812	9556	9610	9663	9716	9770	9823	9877	9930	9984	91 0037	53
813	91 0091	91 0144	91 0197	91 0251	91 0304	91 0358	91 0411	91 0464	91 0518	0571	53
814	0624	0678	0731	0784	0838	0891	0944	0998	1051	1104	53
815	91 1158	91 1211	91 1264	91 1317	91 1371	91 1424	91 1477	91 1530	91 1584	91 1637	53
816	1690	1743	1797	1850	1903	1956	2009	2063	2116	2169	53
817	2222	2275	2328	2381	2435	2488	2541	2594	2647	2700	53
818	2753	2806	2859	2913	2966	3019	3072	3125	3178	3231	53
819	3284	3337	3390	3443	3496	3549	3602	3655	3708	3761	53
N.	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
820	91 3814	91 3867	91 3920	91 3973	91 4026	91 4079	91 4132	91 4184	91 4237	91 4290	53
821	4343	4396	4449	4502	4555	4608	4660	4713	4766	4819	53
822	4872	4925	4977	5030	5083	5136	5189	5241	5294	5347	53
823	5400	5453	5505	5558	5611	5664	5716	5769	5822	5875	53
824	5927	5980	6033	6085	6138	6191	6243	6296	6349	6401	53
825	91 6454	91 6507	91 6559	91 6612	91 6664	91 6717	91 6770	91 6822	91 6875	91 6927	53
826	6980	7033	7085	7138	7190	7243	7295	7348	7400	7453	53
827	7506	7558	7611	7663	7716	7768	7820	7873	7925	7978	52
828	8030	8083	8135	8188	8240	8293	8345	8397	8450	8502	52
829	8555	8607	8659	8712	8764	8816	8869	8921	8973	9026	52
830	91 9078	91 9130	91 9183	91 9235	91 9287	91 9340	91 9392	91 9444	91 9496	91 9549	52
831	9601	9653	9706	9758	9810	9862	9914	9967	92 0019	92 0071	52
832	92 0123	92 0176	92 0228	92 0280	92 0332	92 0384	92 0436	92 0489	0541	0593	52
833	0645	0697	0749	0801	0853	0906	0958	1010	1062	1114	52
834	1166	1218	1270	1322	1374	1426	1478	1530	1582	1634	52
835	92 1686	92 1738	92 1790	92 1842	92 1894	92 1946	92 1998	92 2050	92 2102	92 2154	52
836	2206	2258	2310	2362	2414	2466	2518	2570	2622	2674	52
837	2725	2777	2829	2881	2933	2985	3037	3089	3140	3192	52
838	3244	3296	3348	3399	3451	3503	3555	3607	3658	3710	52
839	3762	3814	3865	3917	3969	4021	4072	4124	4176	4228	52
840	92 4279	92 4331	92 4383	92 4434	92 4486	92 4538	92 4589	92 4641	92 4693	92 4744	52
841	4796	4848	4899	4951	5003	5054	5106	5157	5209	5261	52
842	5312	5364	5415	5467	5518	5570	5621	5673	5725	5776	52
843	5828	5879	5931	5982	6034	6085	6137	6188	6240	6291	51
844	6342	6394	6445	6497	6548	6600	6651	6702	6754	6805	51
845	92 6857	92 6908	92 6959	92 7011	92 7062	92 7114	92 7165	92 7216	92 7268	92 7319	51
846	7370	7422	7473	7524	7576	7627	7678	7730	7781	7832	51
847	7883	7935	7986	8037	8088	8140	8191	8242	8293	8345	51
848	8396	8447	8498	8549	8601	8652	8703	8754	8805	8857	51
849	8908	8959	9010	9061	9112	9163	9215	9266	9317	9368	51
850	92 9419	92 9470	92 9521	92 9572	92 9623	92 9674	92 9725	92 9776	92 9827	92 9879	51
851	9930	9981	93 0032	93 0083	93 0134	93 0185	93 0236	93 0287	93 0338	93 0389	51
852	93 0440	93 0491	0542	0592	0643	0694	0745	0796	0847	0898	51
853	0949	1000	1051	1102	1153	1204	1254	1305	1356	1407	51
854	1458	1509	1560	1610	1661	1712	1763	1814	1865	1915	51
855	93 1966	93 2017	93 2068	93 2118	93 2169	93 2220	93 2271	93 2322	93 2372	93 2423	51
856	2474	2524	2575	2626	2677	2727	2778	2829	2879	2930	51
857	2981	3031	3082	3133	3183	3234	3285	3335	3386	3437	51
858	3487	3538	3589	3639	3690	3740	3791	3841	3892	3943	51
859	3993	4044	4094	4145	4195	4246	4296	4347	4397	4448	51
860	93 4498	93 4549	93 4599	93 4650	93 4700	93 4751	93 4801	93 4852	93 4902	93 4953	50
861	5003	5054	5104	5154	5205	5255	5306	5356	5406	5457	50
862	5507	5558	5608	5658	5709	5759	5809	5860	5910	5960	50
863	6011	6061	6111	6162	6212	6262	6313	6363	6413	6463	50
864	6514	6564	6614	6665	6715	6765	6815	6865	6916	6966	50
865	93 7016	93 7066	93 7117	93 7167	93 7217	93 7267	93 7317	93 7367	93 7418	93 7468	50
866	7518	7568	7618	7668	7718	7769	7819	7869	7919	7969	50
867	8019	8069	8119	8169	8219	8269	8320	8370	8420	8470	50
868	8520	8570	8620	8670	8720	8770	8820	8870	8920	8970	50
869	9020	9070	9120	9170	9220	9270	9320	9369	9419	9469	50
870	93 9519	93 9569	93 9619	93 9669	93 9719	93 9769	93 9819	93 9869	93 9918	93 9968	50
871	94 0018	94 0068	94 0118	94 0168	94 0218	94 0267	94 0317	94 0367	94 0417	94 0467	50
872	0516	0566	0616	0666	0716	0765	0815	0865	0915	0964	50
873	1014	1064	1114	1163	1213	1263	1313	1362	1412	1462	50
874	1511	1561	1611	1660	1710	1760	1809	1859	1909	1958	50
875	94 2008	94 2058	94 2107	94 2157	94 2207	94 2256	94 2306	94 2355	94 2405	94 2455	50
876	2504	2554	2603	2653	2702	2752	2801	2851	2901	2950	50
877	3000	3049	3099	3148	3198	3247	3297	3346	3396	3445	49
878	3495	3544	3593	3643	3692	3742	3791	3841	3890	3939	49
879	3989	4038	4088	4137	4186	4236	4285	4335	4384	4433	49
N.	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
880	94 4483	94 4532	94 4581	94 4631	94 4680	94 4729	94 4779	94 4828	94 4877	94 4927	49
881	4976	5025	5074	5124	5173	5222	5272	5321	5370	5419	49
882	5469	5518	5567	5616	5665	5715	5764	5813	5862	5912	49
883	5961	6010	6059	6108	6157	6207	6256	6305	6354	6403	49
884	6452	6501	6551	6600	6649	6698	6747	6796	6845	6894	49
885	94 6943	94 6992	94 7041	94 7090	94 7140	94 7189	94 7238	94 7287	94 7336	94 7385	49
886	7434	7483	7532	7581	7630	7679	7728	7777	7826	7875	49
887	7924	7973	8022	8070	8119	8168	8217	8266	8315	8364	49
888	8413	8462	8511	8560	8609	8657	8706	8755	8804	8853	49
889	8902	8951	8999	9048	9097	9146	9195	9244	9292	9341	49
890	94 9390	94 9439	94 9488	94 9536	94 9585	94 9634	94 9683	94 9731	94 9780	94 9829	49
891	9878	9926	9975	95 0024	95 0073	95 0121	95 0170	95 0219	95 0267	95 0316	49
892	95 0365	95 0414	95 0462	0511	0560	0608	0657	0706	0754	0803	49
893	0851	0900	0949	0997	1046	1095	1143	1192	1240	1289	49
894	1338	1386	1435	1483	1532	1580	1629	1677	1726	1775	49
895	95 1823	95 1872	95 1920	95 1969	95 2017	95 2066	95 2114	95 2163	95 2211	95 2260	48
896	2308	2356	2405	2453	2502	2550	2599	2647	2696	2744	48
897	2792	2841	2889	2938	2986	3034	3083	3131	3180	3228	48
898	3276	3325	3373	3421	3470	3518	3566	3615	3663	3711	48
899	3760	3808	3856	3905	3953	4001	4049	4098	4146	4194	48
900	95 4243	95 4291	95 4339	95 4387	95 4435	95 4484	95 4532	95 4580	95 4628	95 4677	48
901	4725	4773	4821	4869	4918	4966	5014	5062	5110	5158	48
902	5207	5255	5303	5351	5399	5447	5495	5543	5592	5640	48
903	5688	5736	5784	5832	5880	5928	5976	6024	6072	6120	48
904	6168	6216	6265	6313	6361	6409	6457	6505	6553	6601	48
905	95 6649	95 6697	95 6745	95 6793	95 6840	95 6888	95 6936	95 6984	95 7032	95 7080	48
906	7128	7176	7224	7272	7320	7368	7416	7464	7512	7559	48
907	7607	7655	7703	7751	7799	7847	7894	7942	7990	8038	48
908	8086	8134	8181	8229	8277	8325	8373	8421	8468	8516	48
909	8564	8612	8659	8707	8755	8803	8850	8898	8946	8994	48
910	95 9041	95 9089	95 9137	95 9185	95 9232	95 9280	95 9328	95 9375	95 9423	95 9471	48
911	9518	9566	9614	9661	9709	9757	9804	9852	9900	9947	48
912	9995	96 0042	96 0090	96 0138	96 0185	96 0233	96 0280	96 0328	96 0376	96 0423	48
913	96 0471	0518	0566	0613	0661	0709	0756	0804	0851	0899	48
914	0946	0994	1041	1089	1136	1184	1231	1279	1326	1374	48
915	96 1421	96 1469	96 1516	96 1563	96 1611	96 1658	96 1706	96 1753	96 1801	96 1848	47
916	1895	1943	1990	2038	2085	2132	2180	2227	2275	2322	47
917	2369	2417	2464	2511	2559	2606	2653	2701	2748	2795	47
918	2843	2890	2937	2985	3032	3079	3126	3174	3221	3268	47
919	3316	3363	3410	3457	3504	3552	3599	3646	3693	3741	47
920	96 3788	96 3835	96 3882	96 3929	96 3977	96 4024	96 4071	96 4118	96 4165	96 4212	47
921	4260	4307	4354	4401	4448	4495	4542	4590	4637	4684	47
922	4731	4778	4825	4872	4919	4966	5013	5061	5108	5155	47
923	5202	5249	5296	5343	5390	5437	5484	5531	5578	5625	47
924	5672	5719	5766	5813	5860	5907	5954	6001	6048	6095	47
925	96 6142	96 6189	96 6236	96 6283	96 6329	96 6376	96 6423	96 6470	96 6517	96 6564	47
926	6611	6658	6705	6752	6799	6845	6892	6939	6986	7033	47
927	7080	7127	7173	7220	7267	7314	7361	7408	7454	7501	47
928	7548	7595	7642	7688	7735	7782	7829	7875	7922	7969	47
929	8016	8062	8109	8156	8203	8249	8296	8343	8390	8436	47
930	96 8483	96 8530	96 8576	96 8623	96 8670	96 8716	96 8763	96 8810	96 8856	96 8903	47
931	8950	8996	9043	9090	9136	9183	9229	9276	9323	9369	47
932	9416	9463	9509	9556	9602	9649	9695	9742	9789	9835	47
933	9882	9928	9975	97 0021	97 0068	97 0114	97 0161	97 0207	97 0254	97 0300	47
934	97 0347	97 0393	97 0440	0486	0533	0579	0626	0672	0719	0765	46
935	97 0812	97 0858	97 0904	97 0951	97 0997	97 1044	97 1090	97 1137	97 1183	97 1229	46
936	1276	1322	1369	1415	1461	1508	1554	1601	1647	1693	46
937	1740	1786	1832	1879	1925	1971	2018	2064	2110	2157	46
938	2203	2249	2295	2342	2388	2434	2481	2527	2573	2619	46
939	2666	2712	2758	2804	2851	2897	2943	2989	3035	3082	46
N.	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
940	97 3128	97 3174	97 3220	97 3266	97 3313	97 3359	97 3405	97 3451	97 3497	97 3543	46
941	3590	3636	3682	3728	3774	3820	3866	3913	3959	4005	46
942	4051	4097	4143	4189	4235	4281	4327	4374	4420	4466	46
943	4512	4558	4604	4650	4696	4742	4788	4834	4880	4926	46
944	4972	5018	5064	5110	5156	5202	5248	5294	5340	5386	46
945	97 5432	97 5478	97 5524	97 5570	97 5616	97 5662	97 5707	97 5753	97 5799	97 5845	46
946	5891	5937	5983	6029	6075	6121	6167	6212	6258	6304	46
947	6350	6396	6442	6488	6533	6579	6625	6671	6717	6763	46
948	6808	6854	6900	6946	6992	7037	7083	7129	7175	7220	46
949	7266	7312	7358	7403	7449	7495	7541	7586	7632	7678	46
950	97 7724	97 7769	97 7815	97 7861	97 7906	97 7952	97 7998	97 8043	97 8089	97 8135	46
951	8181	8226	8272	8317	8363	8409	8454	8500	8546	8591	46
952	8637	8683	8728	8774	8819	8865	8911	8956	9002	9047	46
953	9093	9138	9184	9230	9275	9321	9366	9412	9457	9503	46
954	9548	9594	9639	9685	9730	9776	9821	9867	9912	9958	46
955	98 0003	98 0049	98 0094	98 0140	98 0185	98 0231	98 0276	98 0322	98 0367	98 0412	45
956	0458	0503	0549	0594	0640	0685	0730	0776	0821	0867	45
957	0912	0957	1003	1048	1093	1139	1184	1229	1275	1320	45
958	1366	1411	1456	1501	1547	1592	1637	1683	1728	1773	45
959	1819	1864	1909	1954	2000	2045	2090	2135	2181	2226	45
960	98 2271	98 2316	98 2362	98 2407	98 2452	98 2497	98 2543	98 2588	98 2633	98 2678	45
961	2723	2769	2814	2859	2904	2949	2994	3040	3085	3130	45
962	3175	3220	3265	3310	3356	3401	3446	3491	3536	3581	45
963	3626	3671	3716	3762	3807	3852	3897	3942	3987	4032	45
964	4077	4122	4167	4212	4257	4302	4347	4392	4437	4482	45
965	98 4527	98 4572	98 4617	98 4662	98 4707	98 4752	98 4797	98 4842	98 4887	98 4932	45
966	4977	5022	5067	5112	5157	5202	5247	5292	5337	5382	45
967	5426	5471	5516	5561	5606	5651	5696	5741	5786	5830	45
968	5875	5920	5965	6010	6055	6100	6144	6189	6234	6279	45
969	6324	6369	6413	6458	6503	6548	6593	6637	6682	6727	45
970	98 6772	98 6817	98 6861	98 6906	98 6951	98 6996	98 7040	98 7085	98 7130	98 7175	45
971	7219	7264	7309	7353	7398	7443	7488	7532	7577	7622	45
972	7666	7711	7756	7800	7845	7890	7934	7979	8024	8068	45
973	8113	8157	8202	8247	8291	8336	8381	8425	8470	8514	45
974	8559	8604	8648	8693	8737	8782	8826	8871	8916	8960	45
975	98 9005	98 9049	98 9094	98 9138	98 9183	98 9227	98 9272	98 9316	98 9361	98 9405	45
976	9450	9494	9539	9583	9628	9672	9717	9761	9806	9850	44
977	9895	9939	9983	99 0028	99 0072	99 0117	99 0161	99 0206	99 0250	99 0294	44
978	99 0339	99 0383	99 0428	0472	0516	0561	0605	0650	0694	0738	44
979	0783	0827	0871	0916	0960	1004	1049	1093	1137	1182	44
980	99 1226	99 1270	99 1315	99 1359	99 1403	99 1448	99 1492	99 1536	99 1580	99 1625	44
981	1669	1713	1758	1802	1846	1890	1935	1979	2023	2067	44
982	2111	2156	2200	2244	2288	2333	2377	2421	2465	2509	44
983	2554	2598	2642	2686	2730	2774	2819	2863	2907	2951	44
984	2995	3039	3083	3127	3172	3216	3260	3304	3348	3392	44
985	99 3436	99 3480	99 3524	99 3568	99 3613	99 3657	99 3701	99 3745	99 3789	99 3833	44
986	3877	3921	3965	4009	4053	4097	4141	4185	4229	4273	44
987	4317	4361	4405	4449	4493	4537	4581	4625	4669	4713	44
988	4757	4801	4845	4889	4933	4977	5021	5065	5108	5152	44
989	5196	5240	5284	5328	5372	5416	5460	5504	5547	5591	44
990	99 5635	99 5679	99 5723	99 5767	99 5811	99 5854	99 5898	99 5942	99 5986	99 6030	44
991	6074	6117	6161	6205	6249	6293	6337	6380	6424	6468	44
992	6512	6555	6599	6643	6687	6731	6774	6818	6862	6906	44
993	6949	6993	7037	7080	7124	7168	7212	7255	7299	7343	44
994	7386	7430	7474	7517	7561	7605	7648	7692	7736	7779	44
995	99 7823	99 7867	99 7910	99 7954	99 7998	99 8041	99 8085	99 8129	99 8172	99 8216	44
996	8259	8303	8347	8390	8434	8477	8521	8564	8608	8652	44
997	8695	8739	8782	8826	8869	8913	8956	9000	9043	9087	44
998	9131	9174	9218	9261	9305	9348	9392	9435	9479	9522	44
999	9565	9609	9652	9696	9739	9783	9826	9870	9913	9957	43
N.	0	1	2	3	4	5	6	7	8	9	D.

TABLE XVIII

LOGARITHMIC SINES, COSINES, TANGENTS AND COTANGENTS,

FOR EVERY

DEGREE AND MINUTE FROM 0° TO 90°.

0°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	− ∞		10.000 000		− ∞		− ∞	60
1	6.463 726	5017.17	.000 000	.00	6.463 726	5017.17	3.536 274	59
2	.764 756	2934.85	.000 000	.00	.764 756	2934.85	.235 244	58
3	.940 847	2082.32	.000 000	.00	.940 847	2082.32	.059 153	57
4	7.065 786	1615.17	.000 000	.00	7.065 786	1615.17	2.934 214	56
5	7.162 696	1319.68	10.000 000	.02	7.162 696	1319.70	2.837 304	55
6	.241 877	1115.78	9.999 999	.00	.241 878	1115.78	.758 122	54
7	.308 824	966.53	.999 999	.00	.308 825	966.53	.691 175	53
8	.366 816	852.53	.999 999	.00	.366 817	852.55	.633 183	52
9	.417 968	762.63	.999 999	.02	.417 970	762.62	.582 030	51
10	7.463 726	689.87	9.999 998	.00	7.463 727	689.88	2.536 273	50
11	.505 118	629.80	.999 998	.02	.505 120	629.82	.494 880	49
12	.542 906	579.37	.999 997	.00	.542 909	579.38	.457 091	48
13	.577 668	536.42	.999 997	.02	.577 672	536.42	.422 328	47
14	.609 853	499.38	.999 996	.00	.609 857	499.38	.390 143	46
15	7.639 816	467.15	9.999 996	.02	7.639 820	467.15	2.360 180	45
16	.667 845	438.80	.999 995	.00	.667 849	438.83	.332 151	44
17	.694 173	413.73	.999 995	.02	.694 179	413.73	.305 821	43
18	.718 997	391.35	.999 994	.02	.719 003	391.35	.280 997	42
19	.742 478	371.27	.999 993	.00	.742 484	371.28	.257 516	41
20	7.764 754	353.15	9.999 993	.02	7.764 761	353.17	2.235 239	40
21	.785 943	336.72	.999 992	.02	.785 951	336.73	.214 049	39
22	.806 146	321.75	.999 991	.02	.806 155	321.75	.193 845	38
23	.825 451	308.05	.999 990	.02	.825 460	308.07	.174 540	37
24	.843 934	295.47	.999 989	.00	.843 944	295.50	.156 056	36
25	7.861 662	283.88	9.999 989	.02	7.861 674	283.90	2.138 326	35
26	.878 695	273.17	.999 988	.02	.878 708	273.18	.121 292	34
27	.895 085	263.23	.999 987	.02	.895 099	263.25	.104 901	33
28	.910 879	254.00	.999 986	.02	.910 894	254.00	.089 106	32
29	.926 119	245.38	.999 985	.03	.926 134	245.40	.073 866	31
30	7.940 842	237.33	9.999 983	.02	7.940 858	237.37	2.059 142	30
31	.955 082	229.80	.999 982	.02	.955 100	229.82	.044 900	29
32	.968 870	222.72	.999 981	.02	.968 889	222.73	.031 111	28
33	.982 233	216.08	.999 980	.02	.982 253	216.10	.017 747	27
34	.995 198	209.82	.999 979	.03	.995 219	209.83	.004 781	26
35	8.007 787	203.90	9.999 977	.02	8.007 809	203.92	1.992 191	25
36	.020 021	198.30	.999 976	.02	.020 044	198.35	.979 956	24
37	.031 919	193.03	.999 975	.03	.031 945	193.03	.968 055	23
38	.043 501	188.00	.999 973	.02	.043 527	188.03	.956 473	22
39	.054 781	183.25	.999 972	.02	.054 809	183.28	.945 191	21
40	8.065 776	178.73	9.999 971	.03	8.065 806	178.75	1.934 194	20
41	.076 500	174.42	.999 969	.02	.076 531	174.43	.923 469	19
42	.086 965	170.30	.999 968	.03	.086 997	170.33	.913 003	18
43	.097 183	166.40	.999 966	.03	.097 217	166.43	.902 783	17
44	.107 167	162.65	.999 964	.02	.107 203	162.67	.892 797	16
45	8.116 926	159.08	9.999 963	.03	8.116 963	159.12	1.883 037	15
46	.126 471	155.65	.999 961	.03	.126 510	155.68	.873 490	14
47	.135 810	152.38	.999 959	.02	.135 851	152.42	.864 149	13
48	.144 953	149.23	.999 958	.03	.144 996	149.27	.855 004	12
49	.153 907	146.23	.999 956	.03	.153 952	146.25	.846 048	11
50	8.162 681	143.32	9.999 954	.03	8.162 727	143.35	1.837 273	10
51	.171 280	140.55	.999 952	.03	.171 328	140.58	.828 672	9
52	.179 713	137.87	.999 950	.03	.179 763	137.88	.820 237	8
53	.187 985	135.28	.999 948	.03	.188 036	135.33	.811 964	7
54	.196 102	132.80	.999 946	.03	.196 156	132.83	.803 844	6
55	8.204 070	130.42	9.999 944	.03	8.204 126	130.45	1.795 874	5
56	.211 895	128.10	.999 942	.03	.211 953	128.13	.788 047	4
57	.219 581	125.88	.999 940	.03	.219 641	125.90	.780 359	3
58	.227 134	123.72	.999 938	.03	.227 195	123.77	.772 805	2
59	.234 557	121.63	.999 936	.03	.234 621	121.67	.765 379	1
60	8.241 855		9.999 934		8.241 921		1.758 079	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

89°

1°

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0	8.241 855	119.63	9.999 934	.03	8.241 921	119.68	1.758 079	60
1	.249 033	117.68	.999 932	.05	.249 102	117.72	.750 898	59
2	.256 094	115.80	.999 929	.03	.256 165	115.83	.743 835	58
3	.263 042	113.98	.999 927	.03	.263 115	114.02	.736 885	57
4	.269 881	112.22	.999 925	.05	.269 956	112.25	.730 044	56
5	8.276 614	110.48	9.999 922	.03	8.276 691	110.53	1.723 309	55
6	.283 243	108.83	.999 920	.03	.283 323	108.88	.716 677	54
7	.289 773	107.23	.999 918	.05	.289 856	107.27	.710 144	53
8	.296 207	105.65	.999 915	.03	.296 292	105.70	.703 708	52
9	.302 546	104.13	.999 913	.05	.302 634	104.17	.697 366	51
10	8.308 794	102.67	9.999 910	.05	8.308 884	102.70	1.691 116	50
11	.314 954	101.22	.999 907	.03	.315 046	101.27	.684 954	49
12	.321 027	99.82	.999 905	.05	.321 122	99.87	.678 878	48
13	.327 016	98.47	.999 902	.05	.327 114	98.52	.672 886	47
14	.332 924	97.15	.999 899	.03	.333 025	97.18	.666 975	46
15	8.338 753	95.85	9.999 897	.05	8.338 856	95.90	1.661 144	45
16	.344 504	94.62	.999 894	.05	.344 610	94.65	.655 390	44
17	.350 181	93.37	.999 891	.05	.350 289	93.43	.649 711	43
18	.355 783	92.20	.999 888	.05	.355 895	92.25	.644 105	42
19	.361 315	91.03	.999 885	.05	.361 430	91.08	.638 570	41
20	8.366 777	89.90	9.999 882	.05	8.366 895	89.95	1.633 105	40
21	.372 171	88.80	.999 879	.05	.372 292	88.83	.627 708	39
22	.377 499	87.72	.999 876	.05	.377 622	87.78	.622 378	38
23	.382 762	86.67	.999 873	.05	.382 889	86.72	.617 111	37
24	.387 962	85.65	.999 870	.05	.388 092	85.70	.611 908	36
25	8.393 101	84.63	9.999 867	.05	8.393 234	84.68	1.606 766	35
26	.398 179	83.67	.999 864	.05	.398 315	83.72	.601 685	34
27	.403 199	82.70	.999 861	.05	.403 338	82.77	.596 662	33
28	.408 161	81.78	.999 858	.07	.408 304	81.82	.591 696	32
29	.413 068	80.85	.999 854	.05	.413 213	80.92	.586 787	31
30	8.417 919	79.97	9.999 851	.05	8.418 068	80.02	1.581 932	30
31	.422 717	79.08	.999 848	.07	.422 869	79.15	.577 131	29
32	.427 462	78.23	.999 844	.05	.427 618	78.28	.572 382	28
33	.432 156	77.40	.999 841	.05	.432 315	77.45	.567 685	27
34	.436 800	76.57	.999 838	.07	.436 962	76.63	.563 038	26
35	8.441 394	75.78	9.999 834	.05	8.441 560	75.83	1.558 440	25
36	.445 941	74.98	.999 831	.07	.446 110	75.05	.553 890	24
37	.450 440	74.22	.999 827	.05	.450 613	74.28	.549 387	23
38	.454 893	73.47	.999 824	.07	.455 070	73.52	.544 930	22
39	.459 301	72.73	.999 820	.07	.459 481	72.80	.540 519	21
40	8.463 665	72.00	9.999 816	.05	8.463 849	72.05	1.536 151	20
41	.467 985	71.30	.999 813	.07	.468 172	71.37	.531 828	19
42	.472 263	70.58	.999 809	.07	.472 454	70.65	.527 546	18
43	.476 498	69.92	.999 805	.07	.476 693	69.98	.523 307	17
44	.480 693	69.25	.999 801	.07	.480 892	69.30	.519 108	16
45	8.484 848	68.58	9.999 797	.05	8.485 050	68.67	1.514 950	15
46	.488 963	67.95	.999 794	.07	.489 170	68.00	.510 830	14
47	.493 040	67.30	.999 790	.07	.493 250	67.38	.506 750	13
48	.497 078	66.70	.999 786	.07	.497 293	66.75	.502 707	12
49	.501 080	66.08	.999 782	.07	.501 298	66.15	.498 702	11
50	8.505 045	65.48	9.999 778	.07	8.505 267	65.55	1.494 733	10
51	.508 974	64.88	.999 774	.08	.509 200	64.97	.490 800	9
52	.512 867	64.32	.999 769	.07	.513 098	64.38	.486 902	8
53	.516 726	63.75	.999 765	.07	.516 961	63.82	.483 039	7
54	.520 551	63.20	.999 761	.07	.520 790	63.27	.479 210	6
55	8.524 343	62.65	9.999 757	.07	8.524 586	62.72	1.475 414	5
56	.528 102	62.10	.999 753	.08	.528 349	62.18	.471 651	4
57	.531 828	61.58	.999 748	.07	.532 080	61.65	.467 920	3
58	.535 523	61.05	.999 744	.07	.535 779	61.13	.464 221	2
59	.539 186	60.55	.999 740	.08	.539 447	60.62	.460 553	1
60	8.542 819		9.999 735		8.543 084		1.456 916	0
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	M.

88°

2°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	8.542 819	60.05	9.999 735	.07	8.543 084	60.12	1.456 916	60
1	.546 422	59.55	.999 731	.08	.546 691	59.62	.453 309	59
2	.549 995	59.07	.999 726	.07	.550 268	59.15	.449 732	58
3	.553 539	58.58	.999 722	.08	.553 817	58.65	.446 183	57
4	.557 054	58.10	.999 717	.07	.557 336	58.20	.442 664	56
5	8.560 540	57.65	9.999 713	.08	8.560 828	57.72	1.439 172	55
6	.563 999	57.20	.999 708	.07	.564 291	57.27	.435 709	54
7	.567 431	56.75	.999 704	.08	.567 727	56.83	.432 273	53
8	.570 836	56.30	.999 699	.08	.571 137	56.38	.428 863	52
9	.574 214	55.87	.999 694	.08	.574 520	55.95	.425 480	51
10	8.577 566	55.43	9.999 689	.07	8.577 877	55.52	1.422 123	50
11	.580 892	55.02	.999 685	.08	.581 208	55.10	.418 792	49
12	.584 193	54.60	.999 680	.08	.584 514	54.68	.415 486	48
13	.587 469	54.20	.999 675	.08	.587 795	54.27	.412 205	47
14	.590 721	53.78	.999 670	.08	.591 051	53.87	.408 949	46
15	8.593 948	53.40	9.999 665	.08	8.594 283	53.48	1.405 717	45
16	.597 152	53.00	.999 660	.08	.597 492	53.08	.402 508	44
17	.600 332	52.62	.999 655	.08	.600 677	52.70	.399 323	43
18	.603 489	52.23	.999 650	.08	.603 839	52.32	.396 161	42
19	.606 623	51.85	.999 645	.08	.606 978	51.93	.393 022	41
20	8.609 734	51.48	9.999 640	.08	8.610 094	51.58	1.389 906	40
21	.612 823	51.13	.999 635	.10	.613 189	51.22	.386 811	39
22	.615 891	50.77	.999 629	.08	.616 262	50.85	.383 738	38
23	.618 937	50.42	.999 624	.08	.619 313	50.50	.380 687	37
24	.621 962	50.05	.999 619	.08	.622 343	50.15	.377 657	36
25	8.624 965	49.72	9.999 614	.10	8.625 352	49.80	1.374 648	35
26	.627 948	49.38	.999 608	.08	.628 340	49.47	.371 660	34
27	.630 911	49.05	.999 603	.10	.631 308	49.13	.368 692	33
28	.633 854	48.70	.999 597	.08	.634 256	48.80	.365 744	32
29	.636 776	48.40	.999 592	.10	.637 184	48.48	.362 816	31
30	8.639 680	48.05	9.999 586	.08	8.640 093	48.15	1.359 907	30
31	.642 563	47.75	.999 581	.10	.642 982	47.85	.357 018	29
32	.645 428	47.43	.999 575	.08	.645 853	47.52	.354 147	28
33	.648 274	47.13	.999 570	.10	.648 704	47.22	.351 296	27
34	.651 102	46.82	.999 564	.10	.651 537	46.92	.348 463	26
35	8.653 911	46.52	9.999 558	.08	8.654 352	46.62	1.345 648	25
36	.656 702	46.22	.999 553	.10	.657 149	46.32	.342 851	24
37	.659 475	45.92	.999 547	.10	.659 928	46.02	.340 072	23
38	.662 230	45.63	.999 541	.10	.662 689	45.73	.337 311	22
39	.664 968	45.35	.999 535	.10	.665 433	45.45	.334 567	21
40	8.667 689	45.07	9.999 529	.08	8.668 160	45.17	1.331 840	20
41	.670 393	44.78	.999 524	.10	.670 870	44.88	.329 130	19
42	.673 080	44.52	.999 518	.10	.673 563	44.60	.326 437	18
43	.675 751	44.23	.999 512	.10	.676 239	44.35	.323 761	17
44	.678 405	43.97	.999 506	.10	.678 900	44.07	.321 100	16
45	8.681 043	43.70	9.999 500	.12	8.681 544	43.80	1.318 456	15
46	.683 665	43.45	.999 493	.10	.684 172	43.53	.315 828	14
47	.686 272	43.18	.999 487	.10	.686 784	43.28	.313 216	13
48	.688 863	42.92	.999 481	.10	.689 381	43.03	.310 619	12
49	.691 438	42.67	.999 475	.10	.691 963	42.77	.308 037	11
50	8.693 998	42.42	9.999 469	.10	8.694 529	42.53	1.305 471	10
51	.696 543	42.17	.999 463	.12	.697 081	42.27	.302 919	9
52	.699 073	41.93	.999 456	.10	.699 617	42.03	.300 383	8
53	.701 589	41.68	.999 450	.12	.702 139	41.78	.297 861	7
54	.704 090	41.45	.999 443	.10	.704 646	41.57	.295 354	6
55	8.706 577	41.20	9.999 437	.10	8.707 140	41.30	1.292 860	5
56	.709 049	40.97	.999 431	.12	.709 618	41.08	.290 382	4
57	.711 507	40.75	.999 424	.10	.712 083	40.85	.287 917	3
58	.713 952	40.52	.999 418	.12	.714 534	40.63	.285 466	2
59	.716 383	40.28	.999 411	.12	.716 972	40.40	.283 028	1
60	8.718 800		9.999 404		8.719 396		1.280 604	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

87°

3°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	8.718 800	40.07	9.999 404	.10	8.719 396	40.17	1.280 604	60
1	.721 204	39.85	.999 398	.12	.721 806	39.97	.278 194	59
2	.723 595	39.62	.999 391	.12	.724 204	39.73	.275 796	58
3	.725 972	39.42	.999 384	.10	.726 588	39.52	.273 412	57
4	.728 337	39.18	.999 378	.12	.728 959	39.30	.271 041	56
5	8.730 688	38.98	9.999 371	.12	8.731 317	39.10	1.268 683	55
6	.733 027	38.78	.999 364	.12	.733 663	38.88	.266 337	54
7	.735 354	38.55	.999 357	.12	.735 996	38.68	.264 004	53
8	.737 667	38.37	.999 350	.12	.738 317	38.48	.261 683	52
9	.739 969	38.17	.999 343	.12	.740 626	38.27	.259 374	51
10	8.742 259	37.95	9.999 336	.12	8.742 922	38.08	1.257 078	50
11	.744 536	37.77	.999 329	.12	.745 207	37.87	.254 793	49
12	.746 802	37.55	.999 322	.12	.747 479	37.68	.252 521	48
13	.749 055	37.37	.999 315	.12	.749 740	37.48	.250 260	47
14	.751 297	37.18	.999 308	.12	.751 989	37.30	.248 011	46
15	8.753 528	36.98	9.999 301	.12	8.754 227	37.10	1.245 773	45
16	.755 747	36.80	.999 294	.12	.756 453	36.92	.243 547	44
17	.757 955	36.60	.999 287	.13	.758 668	36.73	.241 332	43
18	.760 151	36.43	.999 279	.12	.760 872	36.55	.239 128	42
19	.762 337	36.23	.999 272	.12	.763 065	36.35	.236 935	41
20	8.764 511	36.07	9.999 265	.13	8.765 246	36.18	1.234 754	40
21	.766 675	35.88	.999 257	.12	.767 417	36.02	.232 583	39
22	.768 828	35.70	.999 250	.13	.769 578	35.82	.230 422	38
23	.770 970	35.52	.999 242	.12	.771 727	35.65	.228 273	37
24	.773 101	35.37	.999 235	.13	.773 866	35.48	.226 134	36
25	8.775 223	35.17	9.999 227	.12	8.775 995	35.32	1.224 005	35
26	.777 333	35.02	.999 220	.13	.778 114	35.13	.221 886	34
27	.779 434	34.83	.999 212	.12	.780 222	34.97	.219 778	33
28	.781 524	34.68	.999 205	.13	.782 320	34.80	.217 680	32
29	.783 605	34.50	.999 197	.13	.784 408	34.63	.215 592	31
30	8.785 675	34.35	9.999 189	.13	8.786 486	34.47	1.213 514	30
31	.787 736	34.18	.999 181	.12	.788 554	34.32	.211 446	29
32	.789 787	34.02	.999 174	.13	.790 613	34.15	.209 387	28
33	.791 828	33.85	.999 166	.13	.792 662	33.98	.207 338	27
34	.793 859	33.70	.999 158	.13	.794 701	33.83	.205 299	26
35	8.795 881	33.55	9.999 150	.13	8.796 731	33.68	1.203 269	25
36	.797 894	33.38	.999 142	.13	.798 752	33.52	.201 248	24
37	.799 897	33.25	.999 134	.13	.800 763	33.37	.199 237	23
38	.801 892	33.07	.999 126	.13	.802 765	33.22	.197 235	22
39	.803 876	32.93	.999 118	.13	.804 758	33.07	.195 242	21
40	8.805 852	32.78	9.999 110	.13	8.806 742	32.92	1.193 258	20
41	.807 819	32.63	.999 102	.13	.808 717	32.77	.191 283	19
42	.809 777	32.48	.999 094	.13	.810 683	32.63	.189 317	18
43	.811 726	32.35	.999 086	.15	.812 641	32.47	.187 359	17
44	.813 667	32.20	.999 077	.13	.814 589	32.33	.185 411	16
45	8.815 599	32.05	9.999 069	.13	8.816 529	32.20	1.183 471	15
46	.817 522	31.90	.999 061	.13	.818 461	32.05	.181 539	14
47	.819 436	31.78	.999 053	.15	.820 384	31.90	.179 616	13
48	.821 343	31.62	.999 044	.13	.822 298	31.78	.177 702	12
49	.823 240	31.50	.999 036	.15	.824 205	31.63	.175 795	11
50	8.825 130	31.35	9.999 027	.13	8.826 103	31.48	1.173 897	10
51	.827 011	31.22	.999 019	.15	.827 992	31.37	.172 008	9
52	.828 884	31.08	.999 010	.13	.829 874	31.23	.170 126	8
53	.830 749	30.97	.999 002	.15	.831 748	31.08	.168 252	7
54	.832 607	30.82	.998 993	.15	.833 613	30.97	.166 387	6
55	8.834 456	30.68	9.998 984	.13	8.835 471	30.83	1.164 529	5
56	.836 297	30.55	.998 976	.15	.837 321	30.70	.162 679	4
57	.838 130	30.43	.998 967	.15	.839 163	30.58	.160 837	3
58	.839 956	30.30	.998 958	.13	.840 998	30.45	.159 002	2
59	.841 774	30.18	.998 950	.15	.842 825	30.32	.157 175	1
60	8.843 585		9.998 941		8.844 644		1.155 356	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

86°

4°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	8.843 585	30.03	9.998 941	.15	8.844 644	30.18	1.155 356	60
1	.845 387	29.93	.998 932	.15	.846 455	30.08	.153 545	59
2	.847 183	29.80	.998 923	.15	.848 260	29.95	.151 740	58
3	.848 971	29.67	.998 914	.15	.850 057	29.82	.149 943	57
4	.850 751	29.57	.998 905	.15	.851 846	29.70	.148 154	56
5	8.852 525	29.43	9.998 896	.15	8.853 628	29.58	1.146 372	55
6	.854 291	29.30	.998 887	.15	.855 403	29.47	.144 597	54
7	.856 049	29.20	.998 878	.15	.857 171	29.35	.142 829	53
8	.857 801	29.08	.998 869	.15	.858 932	29.23	.141 068	52
9	.859 546	28.95	.998 860	.15	.860 686	29.12	.139 314	51
10	8.861 283	28.85	9.998 851	.17	8.862 433	29.00	1.137 567	50
11	.863 014	28.73	.998 841	.15	.864 173	28.88	.135 827	49
12	.864 738	28.62	.998 832	.15	.865 906	28.77	.134 094	48
13	.866 455	28.50	.998 823	.17	.867 632	28.65	.132 368	47
14	.868 165	28.38	.998 813	.15	.869 351	28.55	.130 649	46
15	8.869 868	28.28	9.998 804	.15	8.871 064	28.43	1.128 936	45
16	.871 565	28.17	.998 795	.17	.872 770	28.32	.127 230	44
17	.873 255	28.05	.998 785	.15	.874 469	28.22	.125 531	43
18	.874 938	27.95	.998 776	.17	.876 162	28.12	.123 838	42
19	.876 615	27.83	.998 766	.15	.877 849	28.00	.122 151	41
20	8.878 285	27.73	9.998 757	.17	8.879 529	27.88	1.120 471	40
21	.879 949	27.63	.998 747	.15	.881 202	27.78	.118 798	39
22	.881 607	27.52	.998 738	.17	.882 869	27.68	.117 131	38
23	.883 258	27.42	.998 728	.17	.884 530	27.58	.115 470	37
24	.884 903	27.32	.998 718	.17	.886 185	27.47	.113 815	36
25	8.886 542	27.20	9.998 708	.15	8.887 833	27.38	1.112 167	35
26	.888 174	27.12	.998 699	.17	.889 476	27.27	.110 524	34
27	.889 801	27.00	.998 689	.17	.891 112	27.17	.108 888	33
28	.891 421	26.90	.998 679	.17	.892 742	27.07	.107 258	32
29	.893 035	26.80	.998 669	.17	.894 366	26.97	.105 634	31
30	8.894 643	26.72	9.998 659	.17	8.895 984	26.87	1.104 016	30
31	.896 246	26.60	.998 649	.17	.897 596	26.78	.102 404	29
32	.897 842	26.50	.998 639	.17	.899 203	26.67	.100 797	28
33	.899 432	26.42	.998 629	.17	.900 803	26.58	.099 197	27
34	.901 017	26.32	.998 619	.17	.902 398	26.48	.097 602	26
35	8.902 596	26.22	9.998 609	.17	8.903 987	26.38	1.096 013	25
36	.904 169	26.12	.998 599	.17	.905 570	26.28	.094 430	24
37	.905 736	26.02	.998 589	.18	.907 147	26.20	.092 853	23
38	.907 297	25.93	.998 578	.17	.908 719	26.10	.091 281	22
39	.908 853	25.85	.998 568	.17	.910 285	26.02	.089 715	21
40	8.910 404	25.75	9.998 558	.17	8.911 846	25.92	1.088 154	20
41	.911 949	25.65	.998 548	.18	.913 401	25.83	.086 599	19
42	.913 488	25.57	.998 537	.17	.914 951	25.73	.085 049	18
43	.915 022	25.47	.998 527	.18	.916 495	25.65	.083 505	17
44	.916 550	25.38	.998 516	.17	.918 034	25.57	.081 966	16
45	8.918 073	25.30	9.998 506	.18	8.919 568	25.47	1.080 432	15
46	.919 591	25.20	.998 495	.17	.921 096	25.38	.078 904	14
47	.921 103	25.12	.998 485	.18	.922 619	25.28	.077 381	13
48	.922 610	25.03	.998 474	.17	.924 136	25.22	.075 864	12
49	.924 112	24.95	.998 464	.18	.925 649	25.12	.074 351	11
50	8.925 609	24.85	9.998 453	.18	8.927 156	25.03	1.072 844	10
51	.927 100	24.78	.998 442	.18	.928 658	24.95	.071 342	9
52	.928 587	24.68	.998 431	.17	.930 155	24.87	.069 845	8
53	.930 068	24.60	.998 421	.18	.931 647	24.78	.068 353	7
54	.931 544	24.52	.998 410	.18	.933 134	24.70	.066 866	6
55	8.933 015	24.43	9.998 399	.18	8.934 616	24.62	1.065 384	5
56	.934 481	24.35	.998 388	.18	.936 093	24.53	.063 907	4
57	.935 942	24.27	.998 377	.18	.937 565	24.45	.062 435	3
58	.937 398	24.20	.998 366	.18	.939 032	24.37	.060 968	2
59	.938 850	24.10	.998 355	.18	.940 494	24.30	.059 506	1
60	8.940 296		9.998 344		8.941 952		1.058 048	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

85°

5°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	8.940 296	24.03	9.998 344	.18	8.941 952	24.20	1.058 048	60
1	.941 738	23.93	.998 333	.18	.943 404	24.13	.056 596	59
2	.943 174	23.87	.998 322	.18	.944 852	24.05	.055 148	58
3	.944 606	23.80	.998 311	.18	.946 295	23.98	.053 705	57
4	.946 034	23.70	.998 300	.18	.947 734	23.90	.052 266	56
5	8.947 456	23.63	9.998 289	.20	8.949 168	23.82	1.050 832	55
6	.948 874	23.55	.998 277	.18	.950 597	23.73	.049 403	54
7	.950 287	23.48	.998 266	.18	.952 021	23.67	.047 979	53
8	.951 696	23.40	.998 255	.20	.953 441	23.58	.046 559	52
9	.953 100	23.32	.998 243	.18	.954 856	23.52	.045 144	51
10	8.954 499	23.25	9.998 232	.20	8.956 267	23.45	1.043 733	50
11	.955 894	23.17	.998 220	.18	.957 674	23.35	.042 326	49
12	.957 284	23.10	.998 209	.20	.959 075	23.30	.040 925	48
13	.958 670	23.03	.998 197	.18	.960 473	23.22	.039 527	47
14	.960 052	22.95	.998 186	.20	.961 866	23.15	.038 134	46
15	8.961 429	22.87	9.998 174	.18	8.963 255	23.07	1.036 745	45
16	.962 801	22.82	.998 163	.20	.964 639	23.00	.035 361	44
17	.964 170	22.73	.998 151	.20	.966 019	22.92	.033 981	43
18	.965 534	22.65	.998 139	.18	.967 394	22.87	.032 606	42
19	.966 893	22.60	.998 128	.20	.968 766	22.78	.031 234	41
20	8.968 249	22.52	9.998 116	.20	8.970 133	22.72	1.029 867	40
21	.969 600	22.45	.998 104	.20	.971 496	22.65	.028 504	39
22	.970 947	22.37	.998 092	.20	.972 855	22.57	.027 145	38
23	.972 289	22.32	.998 080	.20	.974 209	22.52	.025 791	37
24	.973 628	22.23	.998 068	.20	.975 560	22.43	.024 440	36
25	8.974 962	22.18	9.998 056	.20	8.976 906	22.37	1.023 094	35
26	.976 293	22.10	.998 044	.20	.978 248	22.30	.021 752	34
27	.977 619	22.03	.998 032	.20	.979 586	22.25	.020 414	33
28	.978 941	21.97	.998 020	.20	.980 921	22.17	.019 079	32
29	.980 259	21.90	.998 008	.20	.982 251	22.10	.017 749	31
30	8.981 573	21.83	9.997 996	.20	8.983 577	22.03	1.016 423	30
31	.982 883	21.77	.997 984	.20	.984 899	21.97	.015 101	29
32	.984 189	21.70	.997 972	.22	.986 217	21.92	.013 783	28
33	.985 491	21.63	.997 959	.20	.987 532	21.83	.012 468	27
34	.986 789	21.57	.997 947	.20	.988 842	21.78	.011 158	26
35	8.988 083	21.52	9.997 935	.22	8.990 149	21.70	1.009 851	25
36	.989 374	21.43	.997 922	.20	.991 451	21.65	.008 549	24
37	.990 660	21.38	.997 910	.22	.992 750	21.58	.007 250	23
38	.991 943	21.32	.997 897	.20	.994 045	21.53	.005 955	22
39	.993 222	21.25	.997 885	.22	.995 337	21.45	.004 663	21
40	8.994 497	21.18	9.997 872	.20	8.996 624	21.40	1.003 376	20
41	.995 768	21.13	.997 860	.22	.997 908	21.33	.002 092	19
42	.997 036	21.05	.997 847	.20	.999 188	21.28	.000 812	18
43	.998 299	21.02	.997 835	.22	9.000 465	21.22	0.999 535	17
44	.999 560	20.93	.997 822	.22	.001 738	21.15	.998 262	16
45	9.000 816	20.88	9.997 809	.20	9.003 007	21.08	0.996 993	15
46	.002 069	20.82	.997 797	.22	.004 272	21.03	.995 728	14
47	.003 318	20.75	.997 784	.22	.005 534	20.97	.994 466	13
48	.004 563	20.70	.997 771	.22	.006 792	20.92	.993 208	12
49	.005 805	20.65	.997 758	.22	.008 047	20.85	.991 953	11
50	9.007 044	20.57	9.997 745	.22	9.009 298	20.80	0.990 702	10
51	.008 278	20.53	.997 732	.22	.010 546	20.73	.989 454	9
52	.009 510	20.45	.997 719	.22	.011 790	20.68	.988 210	8
53	.010 737	20.42	.997 706	.22	.013 031	20.62	.986 969	7
54	.011 962	20.33	.997 693	.22	.014 268	20.57	.985 732	6
55	9.013 182	20.30	9.997 680	.22	9.015 502	20.50	0.984 498	5
56	.014 400	20.22	.997 667	.22	.016 732	20.45	.983 268	4
57	.015 613	20.18	.997 654	.22	.017 959	20.40	.982 041	3
58	.016 824	20.12	.997 641	.22	.019 183	20.33	.980 817	2
59	.018 031	20.07	.997 628	.23	.020 403	20.28	.979 597	1
60	9.019 235		9.997 614		9.021 620		0.978 380	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

84°

6°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.019 235	20.00	9.997 614	.22	9.021 620	20.23	0.978 380	60
1	.020 435	19.95	.997 601	.22	.022 834	20.17	.977 166	59
2	.021 632	19.88	.997 588	.23	.024 044	20.12	.975 956	58
3	.022 825	19.85	.997 574	.22	.025 251	20.07	.974 749	57
4	.024 016	19.78	.997 561	.23	.026 455	20.00	.973 545	56
5	9.025 203	19.72	9.997 547	.22	9.027 655	19.95	0.972 345	55
6	.026 386	19.68	.997 534	.23	.028 852	19.90	.971 148	54
7	.027 567	19.62	.997 520	.22	.030 046	19.85	.969 954	53
8	.028 744	19.57	.997 507	.23	.031 237	19.80	.968 763	52
9	.029 918	19.52	.997 493	.22	.032 425	19.73	.967 575	51
10	9.031 089	19.47	9.997 480	.23	9.033 609	19.70	0.966 391	50
11	.032 257	19.40	.997 466	.23	.034 791	19.63	.965 209	49
12	.033 421	19.35	.997 452	.22	.035 969	19.58	.964 031	48
13	.034 582	19.32	.997 439	.23	.037 144	19.53	.962 856	47
14	.035 741	19.25	.997 425	.23	.038 316	19.48	.961 684	46
15	9.036 896	19.20	9.997 411	.23	9.039 485	19.43	0.960 515	45
16	.038 048	19.15	.997 397	.23	.040 651	19.37	.959 349	44
17	.039 197	19.08	.997 383	.23	.041 813	19.33	.958 187	43
18	.040 342	19.05	.997 369	.23	.042 973	19.28	.957 027	42
19	.041 485	19.00	.997 355	.23	.044 130	19.23	.955 870	41
20	9.042 625	18.95	9.997 341	.23	9.045 284	19.17	0.954 716	40
21	.043 762	18.88	.997 327	.23	.046 434	19.13	.953 566	39
22	.044 895	18.85	.997 313	.23	.047 582	19.08	.952 418	38
23	.046 026	18.80	.997 299	.23	.048 727	19.03	.951 273	37
24	.047 154	18.75	.997 285	.23	.049 869	18.98	.950 131	36
25	9.048 279	18.68	9.997 271	.23	9.051 008	18.93	0.948 992	35
26	.049 400	18.65	.997 257	.25	.052 144	18.88	.947 856	34
27	.050 519	18.60	.997 242	.23	.053 277	18.83	.946 723	33
28	.051 635	18.57	.997 228	.23	.054 407	18.80	.945 593	32
29	.052 749	18.50	.997 214	.25	.055 535	18.73	.944 465	31
30	9.053 859	18.45	9.997 199	.23	9.056 659	18.70	0.943 341	30
31	.054 966	18.42	.997 185	.25	.057 781	18.65	.942 219	29
32	.056 071	18.35	.997 170	.23	.058 900	18.60	.941 100	28
33	.057 172	18.32	.997 156	.25	.060 016	18.57	.939 984	27
34	.058 271	18.27	.997 141	.23	.061 130	18.50	.938 870	26
35	9.059 367	18.22	9.997 127	.25	9.062 240	18.47	0.937 760	25
36	.060 460	18.18	.997 112	.23	.063 348	18.42	.936 652	24
37	.061 551	18.13	.997 098	.25	.064 453	18.38	.935 547	23
38	.062 639	18.08	.997 083	.25	.065 556	18.32	.934 444	22
39	.063 724	18.03	.997 068	.25	.066 655	18.28	.933 345	21
40	9.064 806	17.98	9.997 053	.23	9.067 752	18.23	0.932 248	20
41	.065 885	17.95	.997 039	.25	.068 846	18.20	.931 154	19
42	.066 962	17.90	.997 024	.25	.069 938	18.15	.930 062	18
43	.068 036	17.85	.997 009	.25	.071 027	18.10	.928 973	17
44	.069 107	17.82	.996 994	.25	.072 113	18.07	.927 887	16
45	9.070 176	17.77	9.996 979	.25	9.073 197	18.02	0.926 803	15
46	.071 242	17.73	.996 964	.25	.074 278	17.97	.925 722	14
47	.072 306	17.67	.996 949	.25	.075 356	17.93	.924 644	13
48	.073 366	17.63	.996 934	.25	.076 432	17.88	.923 568	12
49	.074 424	17.60	.996 919	.25	.077 505	17.85	.922 495	11
50	9.075 480	17.55	9.996 904	.25	9.078 576	17.80	0.921 424	10
51	.076 533	17.50	.996 889	.25	.079 644	17.77	.920 356	9
52	.077 583	17.47	.996 874	.27	.080 710	17.72	.919 290	8
53	.078 631	17.42	.996 858	.25	.081 773	17.67	.918 227	7
54	.079 676	17.38	.996 843	.25	.082 833	17.63	.917 167	6
55	9.080 719	17.33	9.996 828	.27	9.083 891	17.60	0.916 109	5
56	.081 759	17.30	.996 812	.25	.084 947	17.55	.915 053	4
57	.082 797	17.25	.996 797	.25	.086 000	17.50	.914 000	3
58	.083 832	17.20	.996 782	.27	.087 050	17.47	.912 950	2
59	.084 864	17.17	.996 766	.25	.088 098	17.43	.911 902	1
60	9.085 894		9.996 751		9.089 144		0.910 856	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

83°

7°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.085 894	17.13	9.996 751	.27	9.089 144	17.38	0.910 856	60
1	.086 922	17.08	.996 735	.25	.090 187	17.35	.909 813	59
2	.087 947	17.05	.996 720	.27	.091 228	17.30	.908 772	58
3	.088 970	17.00	.996 704	.27	.092 266	17.27	.907 734	57
4	.089 990	16.97	.996 688	.25	.093 302	17.23	.906 698	56
5	9.091 008	16.93	9.996 673	.27	9.094 336	17.18	0.905 664	55
6	.092 024	16.88	.996 657	.27	.095 367	17.13	.904 633	54
7	.093 037	16.83	.996 641	.27	.096 395	17.12	.903 605	53
8	.094 047	16.82	.996 625	.25	.097 422	17.07	.902 578	52
9	.095 056	16.77	.996 610	.27	.098 446	17.03	.901 554	51
10	9.096 062	16.72	9.996 594	.27	9.099 468	16.98	0.900 532	50
11	.097 065	16.68	.996 578	.27	.100 487	16.95	.899 513	49
12	.098 066	16.65	.996 562	.27	.101 504	16.92	.898 496	48
13	.099 065	16.62	.996 546	.27	.102 519	16.88	.897 481	47
14	.100 062	16.57	.996 530	.27	.103 532	16.83	.896 468	46
15	9.101 056	16.53	9.996 514	.27	9.104 542	16.80	0.895 458	45
16	.102 048	16.48	.996 498	.27	.105 550	16.77	.894 450	44
17	.103 037	16.47	.996 482	.28	.106 556	16.72	.893 444	43
18	.104 025	16.42	.996 465	.27	.107 559	16.68	.892 441	42
19	.105 010	16.37	.996 449	.27	.108 560	16.65	.891 440	41
20	9.105 992	16.35	9.996 433	.27	9.109 559	16.62	0.890 441	40
21	.106 973	16.30	.996 417	.28	.110 556	16.58	.889 444	39
22	.107 951	16.27	.996 400	.27	.111 551	16.53	.888 449	38
23	.108 927	16.23	.996 384	.27	.112 543	16.50	.887 457	37
24	.109 901	16.20	.996 368	.28	.113 533	16.47	.886 467	36
25	9.110 873	16.15	9.996 351	.27	9.114 521	16.43	0.885 479	35
26	.111 842	16.12	.996 335	.28	.115 507	16.40	.884 493	34
27	.112 809	16.08	.996 318	.27	.116 491	16.35	.883 509	33
28	.113 774	16.05	.996 302	.28	.117 472	16.33	.882 528	32
29	.114 737	16.02	.996 285	.27	.118 452	16.28	.881 548	31
30	9.115 698	15.97	9.996 269	.28	9.119 429	16.25	0.880 571	30
31	.116 656	15.95	.996 252	.28	.120 404	16.22	.879 596	29
32	.117 613	15.90	.996 235	.27	.121 377	16.18	.878 623	28
33	.118 567	15.87	.996 219	.28	.122 348	16.15	.877 652	27
34	.119 519	15.83	.996 202	.28	.123 317	16.12	.876 683	26
35	9.120 469	15.80	9.996 185	.28	9.124 284	16.08	0.875 716	25
36	.121 417	15.75	.996 168	.28	.125 249	16.03	.874 751	24
37	.122 362	15.73	.996 151	.28	.126 211	16.02	.873 789	23
38	.123 306	15.70	.996 134	.28	.127 172	15.97	.872 828	22
39	.124 248	15.65	.996 117	.28	.128 130	15.95	.871 870	21
40	9.125 187	15.63	9.996 100	.28	9.129 087	15.90	0.870 913	20
41	.126 125	15.58	.996 083	.28	.130 041	15.88	.869 959	19
42	.127 060	15.55	.996 066	.28	.130 994	15.83	.869 006	18
43	.127 993	15.53	.996 049	.28	.131 944	15.82	.868 056	17
44	.128 925	15.48	.996 032	.28	.132 893	15.77	.867 107	16
45	9.129 854	15.45	9.996 015	.28	9.133 839	15.75	0.866 161	15
46	.130 781	15.42	.995 998	.30	.134 784	15.70	.865 216	14
47	.131 706	15.40	.995 980	.28	.135 726	15.68	.864 274	13
48	.132 630	15.35	.995 963	.28	.136 667	15.63	.863 333	12
49	.133 551	15.32	.995 946	.30	.137 605	15.62	.862 395	11
50	9.134 470	15.28	9.995 928	.28	9.138 542	15.57	0.861 458	10
51	.135 387	15.27	.995 911	.28	.139 476	15.55	.860 524	9
52	.136 303	15.22	.995 894	.30	.140 409	15.52	.859 591	8
53	.137 216	15.20	.995 876	.28	.141 340	15.48	.858 660	7
54	.138 128	15.15	.995 859	.30	.142 269	15.45	.857 731	6
55	9.139 037	15.12	9.995 841	.30	9.143 196	15.42	0.856 804	5
56	.139 944	15.10	.995 823	.28	.144 121	15.38	.855 879	4
57	.140 850	15.07	.995 806	.30	.145 044	15.37	.854 956	3
58	.141 754	15.02	.995 788	.28	.145 966	15.32	.854 034	2
59	.142 655	15.00	.995 771	.30	.146 885	15.30	.853 115	1
60	9.143 555		9.995 753		9.147 803		0.852 197	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

82°

8°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.143 555	14.97	9.995 753	.30	9.147 803	15.25	0.852 197	60
1	.144 453	14.93	.995 735	.30	.148 718	15.23	.851 282	59
2	.145 349	14.90	.995 717	.30	.149 632	15.20	.850 368	58
3	.146 243	14.88	.995 699	.30	.150 544	15.17	.849 456	57
4	.147 136	14.83	.995 681	.28	.151 454	15.15	.848 546	56
5	9.148 026	14.82	9.995 664	.30	9.152 363	15.10	0.847 637	55
6	.148 915	14.78	.995 646	.30	.153 269	15.08	.846 731	54
7	.149 802	14.73	.995 628	.30	.154 174	15.05	.845 826	53
8	.150 686	14.72	.995 610	.32	.155 077	15.02	.844 923	52
9	.151 569	14.70	.995 591	.30	.155 978	14.98	.844 022	51
10	9.152 451	14.65	9.995 573	.30	9.156 877	14.97	0.843 123	50
11	.153 330	14.63	.995 555	.30	.157 775	14.93	.842 225	49
12	.154 208	14.58	.995 537	.30	.158 671	14.90	.841 329	48
13	.155 083	14.57	.995 519	.30	.159 565	14.87	.840 435	47
14	.155 957	14.55	.995 501	.32	.160 457	14.83	.839 543	46
15	9.156 830	14.50	9.995 482	.30	9.161 347	14.82	0.838 653	45
16	.157 700	14.48	.995 464	.30	.162 236	14.78	.837 764	44
17	.158 569	14.43	.995 446	.32	.163 123	14.75	.836 877	43
18	.159 435	14.43	.995 427	.30	.164 008	14.73	.835 992	42
19	.160 301	14.38	.995 409	.32	.164 892	14.70	.835 108	41
20	9.161 164	14.35	9.995 390	.30	9.165 774	14.67	0.834 226	40
21	.162 025	14.33	.995 372	.32	.166 654	14.63	.833 346	39
22	.162 885	14.30	.995 353	.32	.167 532	14.62	.832 468	38
23	.163 743	14.28	.995 334	.30	.168 409	14.58	.831 591	37
24	.164 600	14.23	.995 316	.32	.169 284	14.55	.830 716	36
25	9.165 454	14.22	9.995 297	.32	9.170 157	14.53	0.829 843	35
26	.166 307	14.20	.995 278	.30	.171 029	14.50	.828 971	34
27	.167 159	14.15	.995 260	.32	.171 899	14.47	.828 101	33
28	.168 008	14.13	.995 241	.32	.172 767	14.45	.827 233	32
29	.168 856	14.10	.995 222	.32	.173 634	14.42	.826 366	31
30	9.169 702	14.08	9.995 203	.32	9.174 499	14.38	0.825 501	30
31	.170 547	14.03	.995 184	.32	.175 362	14.37	.824 638	29
32	.171 389	14.02	.995 165	.32	.176 224	14.33	.823 776	28
33	.172 230	14.00	.995 146	.32	.177 084	14.30	.822 916	27
34	.173 070	13.97	.995 127	.32	.177 942	14.28	.822 058	26
35	9.173 908	13.93	9.995 108	.32	9.178 799	14.27	0.821 201	25
36	.174 744	13.90	.995 089	.32	.179 655	14.22	.820 345	24
37	.175 578	13.88	.995 070	.32	.180 508	14.20	.819 492	23
38	.176 411	13.85	.995 051	.32	.181 360	14.18	.818 640	22
39	.177 242	13.83	.995 032	.32	.182 211	14.13	.817 789	21
40	9.178 072	13.80	9.995 013	.33	9.183 059	14.13	0.816 941	20
41	.178 900	13.77	.994 993	.32	.183 907	14.08	.816 093	19
42	.179 726	13.75	.994 974	.32	.184 752	14.08	.815 248	18
43	.180 551	13.72	.994 955	.33	.185 597	14.03	.814 403	17
44	.181 374	13.70	.994 935	.32	.186 439	14.02	.813 561	16
45	9.182 196	13.67	9.994 916	.33	9.187 280	14.00	0.812 720	15
46	.183 016	13.63	.994 896	.32	.188 120	13.97	.811 880	14
47	.183 834	13.62	.994 877	.33	.188 958	13.93	.811 042	13
48	.184 651	13.58	.994 857	.32	.189 794	13.92	.810 206	12
49	.185 466	13.57	.994 838	.33	.190 629	13.88	.809 371	11
50	9.186 280	13.53	9.994 818	.33	9.191 462	13.87	0.808 538	10
51	.187 092	13.52	.994 798	.32	.192 294	13.83	.807 706	9
52	.187 903	13.48	.994 779	.33	.193 124	13.82	.806 876	8
53	.188 712	13.45	.994 759	.33	.193 953	13.78	.806 047	7
54	.189 519	13.43	.994 739	.32	.194 780	13.77	.805 220	6
55	9.190 325	13.42	9.994 720	.33	9.195 606	13.73	0.804 394	5
56	.191 130	13.38	.994 700	.33	.196 430	13.72	.803 570	4
57	.191 933	13.35	.994 680	.33	.197 253	13.68	.802 747	3
58	.192 734	13.33	.994 660	.33	.198 074	13.67	.801 926	2
59	.193 534	13.30	.994 640	.33	.198 894	13.65	.801 106	1
60	9.194 332		9.994 620		9.199 713		0.800 287	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

81°

9°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.194 332	13.28	9.994 620	.33	9.199 713	13.60	0.800 287	60
1	.195 129	13.27	.994 600	.33	.200 529	13.60	.799 471	59
2	.195 925	13.23	.994 580	.33	.201 345	13.57	.798 655	58
3	.196 719	13.20	.994 560	.33	.202 159	13.53	.797 841	57
4	.197 511	13.18	.994 540	.35	.202 971	13.52	.797 029	56
5	9.198 302	13.15	9.994 519	.33	9.203 782	13.50	0.796 218	55
6	.199 091	13.13	.994 499	.33	.204 592	13.47	.795 408	54
7	.199 879	13.12	.994 479	.33	.205 400	13.45	.794 600	53
8	.200 666	13.08	.994 459	.35	.206 207	13.43	.793 793	52
9	.201 451	13.05	.994 438	.33	.207 013	13.40	.792 987	51
10	9.202 234	13.05	9.994 418	.33	9.207 817	13.37	0.792 183	50
11	.203 017	13.00	.994 398	.35	.208 619	13.35	.791 381	49
12	.203 797	13.00	.994 377	.33	.209 420	13.33	.790 580	48
13	.204 577	12.95	.994 357	.35	.210 220	13.30	.789 780	47
14	.205 354	12.95	.994 336	.33	.211 018	13.28	.788 982	46
15	9.206 131	12.92	9.994 316	.35	9.211 815	13.27	0.788 185	45
16	.206 906	12.88	.994 295	.35	.212 611	13.23	.787 389	44
17	.207 679	12.88	.994 274	.33	.213 405	13.22	.786 595	43
18	.208 452	12.83	.994 254	.35	.214 198	13.18	.785 802	42
19	.209 222	12.83	.994 233	.35	.214 989	13.18	.785 011	41
20	9.209 992	12.80	9.994 212	.35	9.215 780	13.13	0.784 220	40
21	.210 760	12.77	.994 191	.33	.216 568	13.13	.783 432	39
22	.211 526	12.75	.994 171	.35	.217 356	13.10	.782 644	38
23	.212 291	12.73	.994 150	.35	.218 142	13.07	.781 858	37
24	.213 055	12.72	.994 129	.35	.218 926	13.07	.781 074	36
25	9.213 818	12.68	9.994 108	.35	9.219 710	13.03	0.780 290	35
26	.214 579	12.65	.994 087	.35	.220 492	13.00	.779 508	34
27	.215 338	12.65	.994 066	.35	.221 272	13.00	.778 728	33
28	.216 097	12.62	.994 045	.35	.222 052	12.97	.777 948	32
29	.216 854	12.58	.994 024	.35	.222 830	12.95	.777 170	31
30	9.217 609	12.57	9.994 003	.35	9.223 607	12.92	0.776 393	30
31	.218 363	12.55	.993 982	.37	.224 382	12.90	.775 618	29
32	.219 116	12.53	.993 960	.35	.225 156	12.88	.774 844	28
33	.219 868	12.50	.993 939	.35	.225 929	12.85	.774 071	27
34	.220 618	12.48	.993 918	.35	.226 700	12.85	.773 300	26
35	9.221 367	12.47	9.993 897	.37	9.227 471	12.80	0.772 529	25
36	.222 115	12.43	.993 875	.35	.228 239	12.80	.771 761	24
37	.222 861	12.42	.993 854	.37	.229 007	12.77	.770 993	23
38	.223 606	12.38	.993 832	.35	.229 773	12.77	.770 227	22
39	.224 349	12.38	.993 811	.37	.230 539	12.72	.769 461	21
40	9.225 092	12.35	9.993 789	.35	9.231 302	12.72	0.768 698	20
41	.225 833	12.33	.993 768	.37	.232 065	12.68	.767 935	19
42	.226 573	12.30	.993 746	.35	.232 826	12.67	.767 174	18
43	.227 311	12.28	.993 725	.37	.233 586	12.65	.766 414	17
44	.228 048	12.27	.993 703	.37	.234 345	12.63	.765 655	16
45	9.228 784	12.23	9.993 681	.35	9.235 103	12.60	0.764 897	15
46	.229 518	12.23	.993 660	.37	.235 859	12.58	.764 141	14
47	.230 252	12.20	.993 638	.37	.236 614	12.57	.763 386	13
48	.230 984	12.18	.993 616	.37	.237 368	12.53	.762 632	12
49	.231 715	12.15	.993 594	.37	.238 120	12.53	.761 880	11
50	9.232 444	12.13	9.993 572	.37	9.238 872	12.50	0.761 128	10
51	.233 172	12.12	.993 550	.37	.239 622	12.48	.760 378	9
52	.233 899	12.10	.993 528	.37	.240 371	12.45	.759 629	8
53	.234 625	12.07	.993 506	.37	.241 118	12.45	.758 882	7
54	.235 349	12.07	.993 484	.37	.241 865	12.42	.758 135	6
55	9.236 073	12.03	9.993 462	.37	9.242 610	12.40	0.757 390	5
56	.236 795	12.00	.993 440	.37	.243 354	12.38	.756 646	4
57	.237 515	12.00	.993 418	.37	.244 097	12.37	.755 903	3
58	.238 235	11.97	.993 396	.37	.244 839	12.33	.755 161	2
59	.238 953	11.95	.993 374	.38	.245 579	12.33	.754 421	1
60	9.239 670		9.993 351		9.246 319		0.753 681	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

80°

10°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.239 670	11.93	9.993 351	.37	9.246 319	12.30	0.753 681	60
1	.240 386	11.92	.993 329	.37	.247 057	12.28	.752 943	59
2	.241 101	11.88	.993 307	.38	.247 794	12.27	.752 206	58
3	.241 814	11.87	.993 284	.37	.248 530	12.23	.751 470	57
4	.242 526	11.85	.993 262	.37	.249 264	12.23	.750 736	56
5	9.243 237	11.83	9.993 240	.38	9.249 998	12.20	0.750 002	55
6	.243 947	11.82	.993 217	.37	.250 730	12.18	.749 270	54
7	.244 656	11.78	.993 195	.38	.251 461	12.17	.748 539	53
8	.245 363	11.77	.993 172	.38	.252 191	12.15	.747 809	52
9	.246 069	11.77	.993 149	.37	.252 920	12.13	.747 080	51
10	9.246 775	11.72	9.993 127	.38	9.253 648	12.10	0.746 352	50
11	.247 478	11.72	.993 104	.38	.254 374	12.10	.745 626	49
12	.248 181	11.70	.993 081	.37	.255 100	12.07	.744 900	48
13	.248 883	11.67	.993 059	.38	.255 824	12.05	.744 176	47
14	.249 583	11.65	.993 036	.38	.256 547	12.03	.743 453	46
15	9.250 282	11.63	9.993 013	.38	9.257 269	12.02	0.742 731	45
16	.250 980	11.62	.992 990	.38	.257 990	12.00	.742 010	44
17	.251 677	11.60	.992 967	.38	.258 710	11.98	.741 290	43
18	.252 373	11.57	.992 944	.38	.259 429	11.95	.740 571	42
19	.253 067	11.57	.992 921	.38	.260 146	11.95	.739 854	41
20	9.253 761	11.53	9.992 898	.38	9.260 863	11.92	0.739 137	40
21	.254 453	11.52	.992 875	.38	.261 578	11.90	.738 422	39
22	.255 144	11.50	.992 852	.38	.262 292	11.88	.737 708	38
23	.255 834	11.48	.992 829	.38	.263 005	11.87	.736 995	37
24	.256 523	11.47	.992 806	.38	.263 717	11.85	.736 283	36
25	9.257 211	11.45	9.992 783	.40	9.264 428	11.83	0.735 572	35
26	.257 898	11.42	.992 759	.38	.265 138	11.82	.734 862	34
27	.258 583	11.42	.992 736	.38	.265 847	11.80	.734 153	33
28	.259 268	11.38	.992 713	.38	.266 555	11.77	.733 445	32
29	.259 951	11.37	.992 690	.40	.267 261	11.77	.732 739	31
30	9.260 633	11.35	9.992 666	.38	9.267 967	11.73	0.732 033	30
31	.261 314	11.33	.992 643	.40	.268 671	11.73	.731 329	29
32	.261 994	11.32	.992 619	.38	.269 375	11.70	.730 625	28
33	.262 673	11.30	.992 596	.40	.270 077	11.70	.729 923	27
34	.263 351	11.27	.992 572	.38	.270 779	11.67	.729 221	26
35	9.264 027	11.27	9.992 549	.40	9.271 479	11.65	0.728 521	25
36	.264 703	11.23	.992 525	.40	.272 178	11.63	.727 822	24
37	.265 377	11.23	.992 501	.38	.272 876	11.62	.727 124	23
38	.266 051	11.20	.992 478	.40	.273 573	11.60	.726 427	22
39	.266 723	11.20	.992 454	.40	.274 269	11.58	.725 731	21
40	9.267 395	11.17	9.992 430	.40	9.274 964	11.57	0.725 036	20
41	.268 065	11.15	.992 406	.40	.275 658	11.55	.724 342	19
42	.268 734	11.13	.992 382	.38	.276 351	11.53	.723 649	18
43	.269 402	11.12	.992 359	.40	.277 043	11.52	.722 957	17
44	.270 069	11.10	.992 335	.40	.277 734	11.50	.722 266	16
45	9.270 735	11.08	9.992 311	.40	9.278 424	11.48	0.721 576	15
46	.271 400	11.07	.992 287	.40	.279 113	11.47	.720 887	14
47	.272 064	11.03	.992 263	.40	.279 801	11.45	.720 199	13
48	.272 726	11.03	.992 239	.42	.280 488	11.43	.719 512	12
49	.273 388	11.02	.992 214	.40	.281 174	11.40	.718 826	11
50	9.274 049	10.98	9.992 190	.40	9.281 858	11.40	0.718 142	10
51	.274 708	10.98	.992 166	.40	.282 542	11.38	.717 458	9
52	.275 367	10.97	.992 142	.40	.283 225	11.37	.716 775	8
53	.276 025	10.93	.992 118	.42	.283 907	11.35	.716 093	7
54	.276 681	10.93	.992 093	.40	.284 588	11.33	.715 412	6
55	9.277 337	10.90	9.992 069	.42	9.285 268	11.32	0.714 732	5
56	.277 991	10.90	.992 044	.40	.285 947	11.28	.714 053	4
57	.278 645	10.87	.992 020	.40	.286 624	11.28	.713 376	3
58	.279 297	10.85	.991 996	.42	.287 301	11.27	.712 699	2
59	.279 948	10.85	.991 971	.40	.287 977	11.25	.712 023	1
60	9.280 599		9.991 947		9.288 652		0.711 348	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

11°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.280 599	10.82	9.991 947	.42	9.288 652	11.23	0.711 348	60
1	.281 248	10.82	.991 922	.42	.289 326	11.22	.710 674	59
2	.281 897	10.78	.991 897	.40	.289 999	11.20	.710 001	58
3	.282 544	10.77	.991 873	.42	.290 671	11.18	.709 329	57
4	.283 190	10.77	.991 848	.42	.291 342	11.18	.708 658	56
5	9.283 836	10.73	9.991 823	.40	9.292 013	11.15	0.707 987	55
6	.284 480	10.73	.991 799	.42	.292 682	11.13	.707 318	54
7	.285 124	10.70	.991 774	.42	.293 350	11.12	.706 650	53
8	.285 766	10.70	.991 749	.42	.294 017	11.12	.705 983	52
9	.286 408	10.67	.991 724	.42	.294 684	11.08	.705 316	51
10	9.287 048	10.67	9.991 699	.42	9.295 349	11.07	0.704 651	50
11	.287 688	10.63	.991 674	.42	.296 013	11.07	.703 987	49
12	.288 326	10.63	.991 649	.42	.296 677	11.03	.703 323	48
13	.288 964	10.60	.991 624	.42	.297 339	11.03	.702 661	47
14	.289 600	10.60	.991 599	.42	.298 001	11.02	.701 999	46
15	9.290 236	10.57	9.991 574	.42	9.298 662	11.00	0.701 338	45
16	.290 870	10.57	.991 549	.42	.299 322	10.97	.700 678	44
17	.291 504	10.55	.991 524	.43	.299 980	10.97	.700 020	43
18	.292 137	10.52	.991 498	.42	.300 638	10.95	.699 362	42
19	.292 768	10.52	.991 473	.42	.301 295	10.93	.698 705	41
20	9.293 399	10.50	9.991 448	.43	9.301 951	10.93	0.698 049	40
21	.294 029	10.48	.991 422	.42	.302 607	10.90	.697 393	39
22	.294 658	10.47	.991 397	.42	.303 261	10.88	.696 739	38
23	.295 286	10.45	.991 372	.43	.303 914	10.88	.696 086	37
24	.295 913	10.43	.991 346	.42	.304 567	10.85	.695 433	36
25	9.296 539	10.42	9.991 321	.43	9.305 218	10.85	0.694 782	35
26	.297 164	10.40	.991 295	.42	.305 869	10.83	.694 131	34
27	.297 788	10.40	.991 270	.43	.306 519	10.82	.693 481	33
28	.298 412	10.37	.991 244	.43	.307 168	10.80	.692 832	32
29	.299 034	10.35	.991 218	.42	.307 816	10.78	.692 184	31
30	9.299 655	10.35	9.991 193	.43	9.308 463	10.77	0.691 537	30
31	.300 276	10.32	.991 167	.43	.309 109	10.75	.690 891	29
32	.300 895	10.32	.991 141	.43	.309 754	10.75	.690 246	28
33	.301 514	10.30	.991 115	.42	.310 399	10.72	.689 601	27
34	.302 132	10.27	.991 090	.43	.311 042	10.72	.688 958	26
35	9.302 748	10.27	9.991 064	.43	9.311 685	10.70	0.688 315	25
36	.303 364	10.25	.991 038	.43	.312 327	10.68	.687 673	24
37	.303 979	10.23	.991 012	.43	.312 968	10.67	.687 032	23
38	.304 593	10.23	.990 986	.43	.313 608	10.65	.686 392	22
39	.305 207	10.20	.990 960	.43	.314 247	10.63	.685 753	21
40	9.305 819	10.18	9.990 934	.43	9.314 885	10.63	0.685 115	20
41	.306 430	10.18	.990 908	.43	.315 523	10.60	.684 477	19
42	.307 041	10.15	.990 882	.45	.316 159	10.60	.683 841	18
43	.307 650	10.15	.990 855	.43	.316 795	10.58	.683 205	17
44	.308 259	10.13	.990 829	.43	.317 430	10.57	.682 570	16
45	9.308 867	10.12	9.990 803	.43	9.318 064	10.55	0.681 936	15
46	.309 474	10.10	.990 777	.45	.318 697	10.55	.681 303	14
47	.310 080	10.08	.990 750	.43	.319 330	10.52	.680 670	13
48	.310 685	10.07	.990 724	.45	.319 961	10.52	.680 039	12
49	.311 289	10.07	.990 697	.43	.320 592	10.50	.679 408	11
50	9.311 893	10.03	9.990 671	.43	9.321 222	10.48	0.678 778	10
51	.312 495	10.03	.990 645	.45	.321 851	10.47	.678 149	9
52	.313 097	10.02	.990 618	.45	.322 479	10.45	.677 521	8
53	.313 698	9.98	.990 591	.43	.323 106	10.45	.676 894	7
54	.314 297	10.00	.990 565	.45	.323 733	10.42	.676 267	6
55	9.314 897	9.97	9.990 538	.45	9.324 358	10.42	0.675 642	5
56	.315 495	9.95	.990 511	.43	.324 983	10.40	.675 017	4
57	.316 092	9.95	.990 485	.45	.325 607	10.40	.674 393	3
58	.316 689	9.92	.990 458	.45	.326 231	10.37	.673 769	2
59	.317 284	9.92	.990 431	.45	.326 853	10.37	.673 147	1
60	9.317 879		9.990 404		9.327 475		0.672 525	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

78°

12°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.317 879	9.90	9.990 404	.43	9.327 475	10.33	0.672 525	60
1	.318 473	9.88	.990 378	.45	.328 095	10.33	.671 905	59
2	.319 066	9.87	.990 351	.45	.328 715	10.32	.671 285	58
3	.319 658	9.85	.990 324	.45	.329 334	10.32	.670 666	57
4	.320 249	9.85	.990 297	.45	.329 953	10.28	.670 047	56
5	9.320 840	9.83	9.990 270	.45	9.330 570	10.28	0.669 430	55
6	.321 430	9.82	.990 243	.47	.331 187	10.27	.668 813	54
7	.322 019	9.80	.990 215	.45	.331 803	10.25	.668 197	53
8	.322 607	9.78	.990 188	.45	.332 418	10.25	.667 582	52
9	.323 194	9.77	.990 161	.45	.333 033	10.22	.666 967	51
10	9.323 780	9.77	9.990 134	.45	9.333 646	10.22	0.666 354	50
11	.324 366	9.73	.990 107	.47	.334 259	10.20	.665 741	49
12	.324 950	9.73	.990 079	.45	.334 871	10.18	.665 129	48
13	.325 534	9.72	.990 052	.45	.335 482	10.18	.664 518	47
14	.326 117	9.72	.990 025	.47	.336 093	10.15	.663 907	46
15	9.326 700	9.68	9.989 997	.45	9.336 702	10.15	0.663 298	45
16	.327 281	9.68	.989 970	.47	.337 311	10.13	.662 689	44
17	.327 862	9.67	.989 942	.45	.337 919	10.13	.662 081	43
18	.328 442	9.65	.989 915	.47	.338 527	10.10	.661 473	42
19	.329 021	9.63	.989 887	.45	.339 133	10.10	.660 867	41
20	9.329 599	9.62	9.989 860	.47	9.339 739	10.08	0.660 261	40
21	.330 176	9.62	.989 832	.47	.340 344	10.07	.659 656	39
22	.330 753	9.60	.989 804	.45	.340 948	10.07	.659 052	38
23	.331 329	9.57	.989 777	.47	.341 552	10.05	.658 448	37
24	.331 903	9.58	.989 749	.47	.342 155	10.03	.657 845	36
25	9.332 478	9.55	9.989 721	.47	9.342 757	10.02	0.657 243	35
26	.333 051	9.55	.989 693	.47	.343 358	10.00	.656 642	34
27	.333 624	9.52	.989 665	.47	.343 958	10.00	.656 042	33
28	.334 195	9.53	.989 637	.45	.344 558	9.98	.655 442	32
29	.334 767	9.50	.989 610	.47	.345 157	9.97	.654 843	31
30	9.335 337	9.48	9.989 582	.48	9.345 755	9.97	0.654 245	30
31	.335 906	9.48	.989 553	.47	.346 353	9.93	.653 647	29
32	.336 475	9.47	.989 525	.47	.346 949	9.93	.653 051	28
33	.337 043	9.45	.989 497	.47	.347 545	9.93	.652 455	27
34	.337 610	9.43	.989 469	.47	.348 141	9.90	.651 859	26
35	9.338 176	9.43	9.989 441	.47	9.348 735	9.90	0.651 265	25
36	.338 742	9.42	.989 413	.47	.349 329	9.88	.650 671	24
37	.339 307	9.40	.989 385	.48	.349 922	9.87	.650 078	23
38	.339 871	9.38	.989 356	.47	.350 514	9.87	.649 486	22
39	.340 434	9.37	.989 328	.47	.351 106	9.85	.648 894	21
40	9.340 996	9.37	9.989 300	.48	9.351 697	9.83	0.648 303	20
41	.341 558	9.35	.989 271	.47	.352 287	9.82	.647 713	19
42	.342 119	9.33	.989 243	.48	.352 876	9.82	.647 124	18
43	.342 679	9.33	.989 214	.47	.353 465	9.80	.646 535	17
44	.343 239	9.30	.989 186	.48	.354 053	9.78	.645 947	16
45	9.343 797	9.30	9.989 157	.48	9.354 640	9.78	0.645 360	15
46	.344 355	9.28	.989 128	.47	.355 227	9.77	.644 773	14
47	.344 912	9.28	.989 100	.48	.355 813	9.75	.644 187	13
48	.345 469	9.25	.989 071	.48	.356 398	9.73	.643 602	12
49	.346 024	9.25	.989 042	.47	.356 982	9.73	.643 018	11
50	9.346 579	9.25	9.989 014	.48	9.357 566	9.72	0.642 434	10
51	.347 134	9.22	.988 985	.48	.358 149	9.70	.641 851	9
52	.347 687	9.22	.988 956	.48	.358 731	9.70	.641 269	8
53	.348 240	9.20	.988 927	.48	.359 313	9.67	.640 687	7
54	.348 792	9.18	.988 898	.48	.359 893	9.68	.640 107	6
55	9.349 343	9.17	9.988 869	.48	9.360 474	9.65	0.639 526	5
56	.349 893	9.17	.988 840	.48	361 053	9.65	.638 947	4
57	.350 443	9.15	.988 811	.48	.361 632	9.63	.638 368	3
58	.350 992	9.13	.988 782	.48	.362 210	9.62	.637 790	2
59	.351 540	9.13	.988 753	.48	.362 787	9.62	.637 213	1
60	9.352 088		9.988 724		9.363 364		0.636 636	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

77°

13°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.352 088	9.12	9.988 724	.48	9.363 364	9.60	0.636 636	60
1	.352 635	9.10	.988 695	.48	.363 940	9.58	.636 060	59
2	.353 181	9.08	.988 666	.50	.364 515	9.58	.635 485	58
3	.353 726	9.08	.988 636	.48	.365 090	9.57	.634 910	57
4	.354 271	9.07	.988 607	.48	.365 664	9.55	.634 336	56
5	9.354 815	9.05	9.988 578	.50	9.366 237	9.55	0.633 763	55
6	.355 358	9.05	.988 548	.48	.366 810	9.53	.633 190	54
7	.355 901	9.03	.988 519	.50	.367 382	9.52	.632 618	53
8	.356 443	9.02	.988 489	.48	.367 953	9.52	.632 047	52
9	.356 984	9.00	.988 460	.50	.368 524	9.50	.631 476	51
10	9.357 524	9.00	9.988 430	.48	9.369 094	9.48	0.630 906	50
11	.358 064	8.98	.988 401	.50	.369 663	9.48	.630 337	49
12	.358 603	8.97	.988 371	.48	.370 232	9.45	.629 768	48
13	.359 141	8.95	.988 342	.50	.370 799	9.47	.629 201	47
14	.359 678	8.95	.988 312	.50	.371 367	9.43	.628 633	46
15	9.360 215	8.95	9.988 282	.50	9.371 933	9.43	0.628 067	45
16	.360 752	8.92	.988 252	.48	.372 499	9.42	.627 501	44
17	.361 287	8.92	.988 223	.50	.373 064	9.42	.626 936	43
18	.361 822	8.90	.988 193	.50	.373 629	9.40	.626 371	42
19	.362 356	8.88	.988 163	.50	.374 193	9.38	.625 807	41
20	9.362 889	8.88	9.988 133	.50	9.374 756	9.38	0.625 244	40
21	.363 422	8.87	.988 103	.50	.375 319	9.37	.624 681	39
22	.363 954	8.85	.988 073	.50	.375 881	9.35	.624 119	38
23	.364 485	8.85	.988 043	.50	.376 442	9.35	.623 558	37
24	.365 016	8.83	.988 013	.50	.377 003	9.33	.622 997	35
25	9.365 546	8.82	9.987 983	.50	9.377 563	9.32	0.622 437	35
26	.366 075	8.82	.987 953	.52	.378 122	9.32	.621 878	34
27	.366 604	8.78	.987 922	.50	.378 681	9.30	.621 319	33
28	.367 131	8.80	.987 892	.50	.379 239	9.30	.620 761	32
29	.367 659	8.77	.987 862	.50	.379 797	9.28	.620 203	31
30	9.368 185	8.77	9.987 832	.52	9.380 354	9.27	0.619 646	30
31	.368 711	8.75	.987 801	.50	.380 910	9.27	.619 090	29
32	.369 236	8.75	.987 771	.52	.381 466	9.23	.618 534	28
33	.369 761	8.73	.987 740	.50	.382 020	9.25	.617 980	27
34	.370 285	8.72	.987 710	.52	.382 575	9.23	.617 425	26
35	9.370 808	8.70	9.987 679	.50	9.383 129	9.22	0.616 871	25
36	.371 330	8.70	.987 649	.52	.383 682	9.20	.616 318	24
37	.371 852	8.68	.987 618	.50	.384 234	9.20	.615 766	23
38	.372 373	8.68	.987 588	.52	.384 786	9.18	.615 214	22
39	.372 894	8.67	.987 557	.52	.385 337	9.18	.614 663	21
40	9.373 414	8.65	9.987 526	.50	9.385 888	9.17	0.614 112	20
41	.373 933	8.65	.987 496	.52	.386 438	9.15	.613 562	19
42	.374 452	8.63	.987 465	.52	.386 987	9.15	.613 013	18
43	.374 970	8.62	.987 434	.52	.387 536	9.13	.612 464	17
44	.375 487	8.60	.987 403	.52	.388 084	9.12	.611 916	16
45	9.376 003	8.60	9.987 372	.52	9.388 631	9.12	0.611 369	15
46	.376 519	8.60	.987 341	.52	.389 178	9.10	.610 822	14
47	.377 035	8.57	.987 310	.52	.389 724	9.10	.610 276	13
48	.377 549	8.57	.987 279	.52	.390 270	9.08	.609 730	12
49	.378 063	8.57	.987 248	.52	.390 815	9.08	.609 185	11
50	9.378 577	8.53	9.987 217	.52	9.391 360	9.05	0.608 640	10
51	.379 089	8.53	.987 186	.52	.391 903	9.07	.608 097	9
52	.379 601	8.53	.987 155	.52	.392 447	9.03	.607 553	8
53	.380 113	8.52	.987 124	.53	.392 989	9.03	.607 011	7
54	.380 624	8.50	.987 092	.52	.393 531	9.03	.606 469	6
55	9.381 134	8.48	9.987 061	.52	9.394 073	9.02	0.605 927	5
56	.381 643	8.48	.987 030	.53	.394 614	9.00	.605 386	4
57	.382 152	8.48	.986 998	.52	.395 154	9.00	.604 846	3
58	.382 661	8.45	.986 967	.52	.395 694	8.98	.604 306	2
59	.383 168	8.45	.986 936	.53	.396 233	8.97	.603 767	1
60	9.383 675		9.986 904		9.396 771		0.603 229	0
	Cos.	D. 1″.	Sin.	D 1″.	Cot.	D. 1″.	Tan.	M.

76°

14°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.383 675	8.45	9.986 904	.52	9.396 771	8.97	0.603 229	60
1	.384 182	8.42	.986 873	.53	.397 309	8.95	.602 691	59
2	.384 687	8.42	.986 841	.53	.397 846	8.95	.602 154	58
3	.385 192	8.42	.986 809	.52	.398 383	8.93	.601 617	57
4	.385 697	8.40	.986 778	.53	.398 919	8.93	.601 081	56
5	9.386 201	8.38	9.986 746	.53	9.399 455	8.92	0.600 545	55
6	.386 704	8.38	.986 714	.52	.399 990	8.90	.600 010	54
7	.387 207	8.37	.986 683	.53	.400 524	8.90	.599 476	53
8	.387 709	8.35	.986 651	.53	.401 058	8.88	.598 942	52
9	.388 210	8.35	.986 619	.53	.401 591	8.88	.598 409	51
10	9.388 711	8.33	9.986 587	.53	9.402 124	8.87	0.597 876	50
11	.389 211	8.33	.986 555	.53	.402 656	8.85	.597 344	49
12	.389 711	8.32	.986 523	.53	.403 187	8.85	.596 813	48
13	.390 210	8.30	.986 491	.53	.403 718	8.85	.596 282	47
14	.390 708	8.30	.986 459	.53	.404 249	8.82	.595 751	46
15	9.391 206	8.28	9.986 427	.53	9.404 778	8.83	0.595 222	45
16	.391 703	8.27	.986 395	.53	.405 308	8.80	.594 692	44
17	.392 199	8.27	.986 363	.53	.405 836	8.80	.594 164	43
18	.392 695	8.27	.986 331	.53	.406 364	8.80	.593 636	42
19	.393 191	8.23	.986 299	.55	.406 892	8.78	.593 108	41
20	9.393 685	8.23	9.986 266	.53	9.407 419	8.77	0.592 581	40
21	.394 179	8.23	.986 234	.53	.407 945	8.77	.592 055	39
22	.394 673	8.22	.986 202	.55	.408 471	8.75	.591 529	38
23	.395 166	8.20	.986 169	.53	.408 996	8.75	.591 004	37
24	.395 658	8.20	.986 137	.55	.409 521	8.73	.590 479	36
25	9.396 150	8.18	9.986 104	.53	9.410 045	8.73	0.589 955	35
26	.396 641	8.18	.986 072	.55	.410 569	8.72	.589 431	34
27	.397 132	8.15	.986 039	.53	.411 092	8.72	.588 908	33
28	.397 621	8.17	.986 007	.55	.411 615	8.70	.588 385	32
29	.398 111	8.15	.985 974	.53	.412 137	8.68	.587 863	31
30	9.398 600	8.13	9.985 942	.55	9.412 658	8.68	0.587 342	30
31	.399 088	8.12	.985 909	.55	.413 179	8.67	.586 821	29
32	.399 575	8.12	.985 876	.55	.413 699	8.67	.586 301	28
33	.400 062	8.12	.985 843	.53	.414 219	8.65	.585 781	27
34	.400 549	8.10	.985 811	.55	.414 738	8.65	.585 262	26
35	9.401 035	8.08	9.985 778	.55	9.415 257	8.63	0.584 743	25
36	.401 520	8.08	.985 745	.55	.415 775	8.63	.584 225	24
37	.402 005	8.07	.985 712	.55	.416 293	8.62	.583 707	23
38	.402 489	8.05	.985 679	.55	.416 810	8.60	.583 190	22
39	.402 972	8.05	.985 646	.55	.417 326	8.60	.582 674	21
40	9.403 455	8.05	9.985 613	.55	9.417 842	8.60	0.582 158	20
41	.403 938	8.03	.985 580	.55	.418 358	8.58	.581 642	19
42	.404 420	8.02	.985 547	.55	.418 873	8.57	.581 127	18
43	.404 901	8.02	.985 514	.57	.419 387	8.57	.580 613	17
44	.405 382	8.00	.985 480	.55	.419 901	8.57	.580 099	16
45	9.405 862	7.98	9.985 447	.55	9.420 415	8.53	0.579 585	15
46	.406 341	7.98	.985 414	.55	.420 927	8.55	.579 073	14
47	.406 820	7.98	.985 381	.57	.421 440	8.53	.578 560	13
48	.407 299	7.97	.985 347	.55	.421 952	8.52	.578 048	12
49	.407 777	7.95	.985 314	.57	.422 463	8.52	.577 537	11
50	9.408 254	7.95	9.985 280	.55	9.422 974	8.50	0.577 026	10
51	.408 731	7.93	.985 247	.57	.423 484	8.48	.576 516	9
52	.409 207	7.92	.985 213	.55	.423 993	8.50	.576 007	8
53	.409 682	7.92	.985 180	.57	.424 503	8.47	.575 497	7
54	.410 157	7.92	.985 146	.55	.425 011	8.47	.574 989	6
55	9.410 632	7.90	9.985 113	.57	9.425 519	8.47	0.574 481	5
56	.411 106	7.88	.985 079	.57	.426 027	8.45	.573 973	4
57	.411 579	7.88	.985 045	.57	.426 534	8.45	.573 466	3
58	.412 052	7.87	.985 011	.55	.427 041	8.43	.572 959	2
59	.412 524	7.87	.984 978	.57	.427 547	8.42	.572 453	1
60	9.412 996		9.984 944		9.428 052		0.571 948	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

75°

15°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.412 996	7.85	9.984 944	.57	9.428 052	8.43	0.571 948	60
1	.413 467	7.85	.984 910	.57	.428 558	8.40	.571 442	59
2	.413 938	7.83	.984 876	.57	.429 062	8.40	.570 938	58
3	.414 408	7.83	.984 842	.57	.429 566	8.40	.570 434	57
4	.414 878	7.82	.984 808	.57	.430 070	8.38	.569 930	56
5	9.415 347	7.80	9.984 774	.57	9.430 573	8.37	0.569 427	55
6	.415 815	7.80	.984 740	.57	.431 075	8.37	.568 925	54
7	.416 283	7.80	.984 706	.57	.431 577	8.37	.568 423	53
8	.416 751	7.77	.984 672	.57	.432 079	8.35	.567 921	52
9	.417 217	7.78	.984 638	.58	.432 580	8.33	.567 420	51
10	9.417 684	7.77	9.984 603	.57	9.433 080	8.33	0.566 920	50
11	.418 150	7.75	.984 569	.57	.433 580	8.33	.566 420	49
12	.418 615	7.73	.984 535	.58	.434 080	8.32	.565 920	48
13	.419 079	7.75	.984 500	.57	.434 579	8.32	.565 421	47
14	.419 544	7.72	.984 466	.57	.435 078	8.30	.564 922	46
15	9.420 007	7.72	9.984 432	.58	9.435 576	8.28	0.564 424	45
16	.420 470	7.72	.984 397	.57	.436 073	8.28	.563 927	44
17	.420 933	7.70	.984 363	.58	.436 570	8.28	.563 430	43
18	.421 395	7.70	.984 328	.57	.437 067	8.27	.562 933	42
19	.421 857	7.68	.984 294	.58	.437 563	8.27	.562 437	41
20	9.422 318	7.67	9.984 259	.58	9.438 059	8.25	0.561 941	40
21	.422 778	7.67	.984 224	.57	.438 554	8.23	.561 446	39
22	.423 238	7.65	.984 190	.58	.439 048	8.25	.560 952	38
23	.423 697	7.65	.984 155	.58	.439 543	8.22	.560 457	37
24	.424 156	7.65	.984 120	.58	.440 036	8.22	.559 964	36
25	9.424 615	7.63	9.984 085	.58	9.440 529	8.22	0.559 471	35
26	.425 073	7.62	.984 050	.58	.441 022	8.20	.558 978	34
27	.425 530	7.62	.984 015	.57	.441 514	8.20	.558 486	33
28	.425 987	7.60	.983 981	.58	.442 006	8.18	.557 994	32
29	.426 443	7.60	.983 946	.58	.442 497	8.18	.557 503	31
30	9.426 899	7.58	9.983 911	.60	9.442 988	8.18	0.557 012	30
31	.427 354	7.58	.983 875	.58	.443 479	8.15	.556 521	29
32	.427 809	7.57	.983 840	.58	.443 968	8.17	.556 032	28
33	.428 263	7.57	.983 805	.58	.444 458	8.15	.555 542	27
34	.428 717	7.55	.983 770	.58	.444 947	8.13	.555 053	26
35	9.429 170	7.55	9.983 735	.58	9.445 435	8.13	0.554 565	25
36	.429 623	7.53	.983 700	.60	.445 923	8.13	.554 077	24
37	.430 075	7.53	.983 664	.58	.446 411	8.12	.553 589	23
38	.430 527	7.52	.983 629	.58	.446 898	8.10	.553 102	22
39	.430 978	7.52	.983 594	.60	.447 384	8.10	.552 616	21
40	9.431 429	7.50	9.983 558	.58	9.447 870	8.10	0.552 130	20
41	.431 879	7.50	.983 523	.60	.448 356	8.08	.551 644	19
42	.432 329	7.48	.983 487	.58	.448 841	8.08	.551 159	18
43	.432 778	7.47	.983 452	.60	.449 326	8.07	.550 674	17
44	.433 226	7.48	.983 416	.58	.449 810	8.07	.550 190	16
45	9.433 675	7.45	9.983 381	.60	9.450 294	8.05	0.549 706	15
46	.434 122	7.45	.983 345	.60	.450 777	8.05	.549 223	14
47	.434 569	7.45	.983 309	.60	.451 260	8.05	.548 740	13
48	.435 016	7.43	.983 273	.58	.451 743	8.03	.548 257	12
49	.435 462	7.43	.983 238	.60	.452 225	8.02	.547 775	11
50	9.435 908	7.42	9.983 202	.60	9.452 706	8.02	0.547 294	10
51	.436 353	7.42	.983 166	.60	.453 187	8.02	.546 813	9
52	.436 798	7.40	.983 130	.60	.453 668	8.00	.546 332	8
53	.437 242	7.40	.983 094	.60	.454 148	8.00	.545 852	7
54	.437 686	7.38	.983 058	.60	.454 628	7.98	.545 372	6
55	9.438 129	7.38	9.983 022	.60	9.455 107	7.98	0.544 893	5
56	.438 572	7.37	.982 986	.60	.455 586	7.97	.544 414	4
57	.439 014	7.37	.982 950	.60	.456 064	7.97	.543 936	3
58	.439 456	7.35	.982 914	.60	.456 542	7.95	.543 458	2
59	.439 897	7.35	.982 878	.60	.457 019	7.95	.542 981	1
60	9.440 338		9.982 842		9.457 496		0.542 504	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

74°

16°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.440 338	7.33	9.982 842	.62	9.457 496	7.95	0.542 504	60
1	.440 778	7.33	.982 805	.60	.457 973	7.93	.542 027	59
2	.441 218	7.33	.982 769	.60	.458 449	7.93	.541 551	58
3	.441 658	7.30	.982 733	.62	.458 925	7.92	.541 075	57
4	.442 096	7.32	.982 696	.60	.459 400	7.92	.540 600	56
5	9.442 535	7.30	9.982 660	.60	9.459 875	7.90	0.540 125	55
6	.442 973	7.28	.982 624	.62	.460 349	7.90	.539 651	54
7	.443 410	7.28	.982 587	.60	.460 823	7.90	.539 177	53
8	.443 847	7.28	.982 551	.62	.461 297	7.88	.538 703	52
9	.444 284	7.27	.982 514	.62	.461 770	7.87	.538 230	51
10	9.444 720	7.25	9.982 477	.60	9.462 242	7.88	0.537 758	50
11	.445 155	7.25	.982 441	.62	.462 715	7.85	.537 285	49
12	.445 590	7.25	.982 404	.62	.463 186	7.87	.536 814	48
13	.446 025	7.23	.982 367	.60	.463 658	7.83	.536 342	47
14	.446 459	7.23	.982 331	.62	.464 128	7.85	.535 872	46
15	9.446 893	7.22	9.982 294	.62	9.464 599	7.83	0.535 401	45
16	.447 326	7.22	.982 257	.62	.465 069	7.83	.534 931	44
17	.447 759	7.20	.982 220	.62	.465 539	7.82	.534 461	43
18	.448 191	7.20	.982 183	.62	.466 008	7.82	.533 992	42
19	.448 623	7.18	.982 146	.62	.466 477	7.80	.533 523	41
20	9.449 054	7.18	9.982 109	.62	9.466 945	7.80	0.533 055	40
21	.449 485	7.17	.982 072	.62	.467 413	7.78	.532 587	39
22	.449 915	7.17	.982 035	.62	.467 880	7.78	.532 120	38
23	.450 345	7.17	.981 998	.62	.468 347	7.78	.531 653	37
24	.450 775	7.15	.981 961	.62	.468 814	7.77	.531 186	36
25	9.451 204	7.13	9.981 924	.63	9.469 280	7.77	0.530 720	35
26	.451 632	7.13	.981 886	.62	.469 746	7.75	.530 254	34
27	.452 060	7.13	.981 849	.62	.470 211	7.75	.529 789	33
28	.452 488	7.12	.981 812	.63	.470 676	7.75	.529 324	32
29	.452 915	7.12	.981 774	.62	.471 141	7.73	.528 859	31
30	9.453 342	7.10	9.981 737	.62	9.471 605	7.73	0.528 395	30
31	.453 768	7.10	.981 700	.63	.472 069	7.72	.527 931	29
32	.454 194	7.08	.981 662	.62	.472 532	7.72	.527 468	28
33	.454 619	7.08	.981 625	.63	.472 995	7.70	.527 005	27
34	.455 044	7.08	.981 587	.63	.473 457	7.70	.526 543	26
35	9.455 469	7.07	9.981 549	.62	9.473 919	7.70	0.526 081	25
36	.455 893	7.05	.981 512	.63	.474 381	7.68	.525 619	24
37	.456 316	7.05	.981 474	.63	.474 842	7.68	.525 158	23
38	.456 739	7.05	.981 436	.62	.475 303	7.67	.524 697	22
39	.457 162	7.03	.981 399	.63	.475 763	7.67	.524 237	21
40	9.457 584	7.03	9.981 361	.63	9.476 223	7.67	0.523 777	20
41	.458 006	7.02	.981 323	.63	.476 683	7.65	.523 317	19
42	.458 427	7.02	.981 285	.63	.477 142	7.65	.522 858	18
43	.458 848	7.00	.981 247	.63	.477 601	7.63	.522 399	17
44	.459 268	7.00	.981 209	.63	.478 059	7.63	.521 941	16
45	9.459 688	7.00	9.981 171	.63	9.478 517	7.63	0.521 483	15
46	.460 108	6.98	.981 133	.63	.478 975	7.62	.521 025	14
47	.460 527	6.98	.981 095	.63	.479 432	7.62	.520 568	13
48	.460 946	6.97	.981 057	.63	.479 889	7.60	.520 111	12
49	.461 364	6.97	.981 019	.63	.480 345	7.60	.519 655	11
50	9.461 782	6.95	9.980 981	.65	9.480 801	7.60	0.519 199	10
51	.462 199	6.95	.980 942	.63	.481 257	7.58	.518 743	9
52	.462 616	6.93	.980 904	.63	.481 712	7.58	.518 288	8
53	.463 032	6.93	.980 866	.65	.482 167	7.57	.517 833	7
54	.463 448	6.93	.980 827	.63	.482 621	7.57	.517 379	6
55	9.463 864	6.92	9.980 789	.65	9.483 075	7.57	0.516 925	5
56	.464 279	6.92	.980 750	.63	.483 529	7.55	.516 471	4
57	.464 694	6.90	.980 712	.65	.483 982	7.55	.516 018	3
58	.465 108	6.90	.980 673	.63	.484 435	7.53	.515 565	2
59	.465 522	6.88	.980 635	.65	.484 887	7.53	.515 113	1
60	9.465 935		9.980 596		9.485 339		0.514 661	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

73°

17°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.465 935	6.88	9.980 596	.63	9.485 339	7.53	0.514 661	60
1	.466 348	6.88	.980 558	.65	.485 791	7.52	.514 209	59
2	.466 761	6.87	.980 519	.65	.486 242	7.52	.513 758	58
3	.467 173	6.87	.980 480	.63	.486 693	7.50	.513 307	57
4	.467 585	6.85	.980 442	.65	.487 143	7.50	.512 857	56
5	9.467 996	6.85	9.980 403	.65	9.487 593	7.50	0.512 407	55
6	.468 407	6.83	.980 364	.65	.488 043	7.48	.511 957	54
7	.468 817	6.83	.980 325	.65	.488 492	7.48	.511 508	53
8	.469 227	6.83	.980 286	.65	.488 941	7.48	.511 059	52
9	.469 637	6.82	.980 247	.65	.489 390	7.47	.510 610	51
10	9.470 046	6.82	9.980 208	.65	9.489 838	7.47	0.510 162	50
11	.470 455	6.80	.980 169	.65	.490 286	7.45	.509 714	49
12	.470 863	6.80	.980 130	.65	.490 733	7.45	.509 267	48
13	.471 271	6.80	.980 091	.65	.491 180	7.45	.508 820	47
14	.471 679	6.78	.980 052	.67	.491 627	7.43	.508 373	46
15	9.472 086	6.77	9.980 012	.65	9.492 073	7.43	0.507 927	45
16	.472 492	6.77	.979 973	.65	.492 519	7.43	.507 481	44
17	.472 898	6.77	.979 934	.65	.492 965	7.42	.507 035	43
18	.473 304	6.77	.979 895	.67	.493 410	7.40	.506 590	42
19	.473 710	6.75	.979 855	.65	.493 854	7.42	.506 146	41
20	9.474 115	6.73	9.979 816	.67	9.494 299	7.40	0.505 701	40
21	.474 519	6.73	.979 776	.65	.494 743	7.38	.505 257	39
22	.474 923	6.73	.979 737	.67	.495 186	7.40	.504 814	38
23	.475 327	6.72	.979 697	.65	.495 630	7.38	.504 370	37
24	.475 730	6.72	.979 658	.67	.496 073	7.37	.503 927	36
25	9.476 133	6.72	9.979 618	.65	9.496 515	7.37	0.503 485	35
26	.476 536	6.70	.979 579	.67	.496 957	7.37	.503 043	34
27	.476 938	6.70	.979 539	.67	.497 399	7.37	.502 601	33
28	.477 340	6.68	.979 499	.67	.497 841	7.35	.502 159	32
29	.477 741	6.68	.979 459	.65	.498 282	7.33	.501 718	31
30	9.478 142	6.67	9.979 420	.67	9.498 722	7.35	0.501 278	30
31	.478 542	6.67	.979 380	.67	.499 163	7.33	.500 837	29
32	.478 942	6.67	.979 340	.67	.499 603	7.32	.500 397	28
33	.479 342	6.65	.979 300	.67	.500 042	7.32	.499 958	27
34	.479 741	6.65	.979 260	.67	.500 481	7.32	.499 519	26
35	9.480 140	6.65	9.979 220	.67	9.500 920	7.32	0.499 080	25
36	.480 539	6.63	.979 180	.67	.501 359	7.30	.498 641	24
37	.480 937	6.62	.979 140	.67	.501 797	7.30	.498 203	23
38	.481 334	6.62	.979 100	.68	.502 235	7.28	.497 765	22
39	.481 731	6.62	.979 059	.67	.502 672	7.28	.497 328	21
40	9.482 128	6.62	9.979 019	.67	9.503 109	7.28	0.496 891	20
41	.482 525	6.60	.978 979	.67	.503 546	7.27	.496 454	19
42	.482 921	6.58	.978 939	.68	.503 982	7.27	.496 018	18
43	.483 316	6.60	.978 898	.67	.504 418	7.27	.495 582	17
44	.483 712	6.58	.978 858	.68	.504 854	7.25	.495 146	16
45	9.484 107	6.57	9.978 817	.67	9.505 289	7.25	0.494 711	15
46	.484 501	6.57	.978 777	.67	.505 724	7.25	.494 276	14
47	.484 895	6.57	.978 737	.68	.506 159	7.23	.493 841	13
48	.485 289	6.55	.978 696	.68	.506 593	7.23	.493 407	12
49	.485 682	6.55	.978 655	.67	.507 027	7.22	.492 973	11
50	9.486 075	6.53	9.978 615	.68	9.507 460	7.22	0.492 540	10
51	.486 467	6.55	.978 574	.68	.507 893	7.22	.492 107	9
52	.486 860	6.52	.978 533	.67	.508 326	7.22	.491 674	8
53	.487 251	6.53	.978 493	.68	.508 759	7.20	.491 241	7
54	.487 643	6.52	.978 452	.68	.509 191	7.18	.490 809	6
55	9.488 034	6.50	9.978 411	.68	9.509 622	7.20	0.490 378	5
56	.488 424	6.50	.978 370	.68	.510 054	7.18	.489 946	4
57	.488 814	6.50	.978 329	.68	.510 485	7.18	.489 515	3
58	.489 204	6.48	.978 288	.68	.510 916	7.17	.489 084	2
59	.489 593	6.48	.978 247	.68	.511 346	7.17	.488 654	1
60	9.489 982		9.978 206		9.511 776		0.488 224	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

72°

18°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.489 982	6.48	9.978 206	.68	9.511 776	7.17	0.488 224	60
1	.490 371	6.47	.978 165	.68	.512 206	7.15	.487 794	59
2	.490 759	6.47	.978 124	.68	.512 635	7.15	.487 365	58
3	.491 147	6.47	.978 083	.68	.513 064	7.15	.486 936	57
4	.491 535	6.45	.978 042	.68	.513 493	7.13	.486 507	56
5	9.491 922	6.43	9.978 001	.70	9.513 921	7.13	0.486 079	55
6	.492 308	6.45	.977 959	.68	.514 349	7.13	.485 651	54
7	.492 695	6.43	.977 918	.68	.514 777	7.12	.485 223	53
8	.493 081	6.42	.977 877	.70	.515 204	7.12	.484 796	52
9	.493 466	6.42	.977 835	.68	.515 631	7.10	.484 369	51
10	9.493 851	6.42	9.977 794	.70	9.516 057	7.12	0.483 943	50
11	.494 236	6.42	.977 752	.68	.516 484	7.10	.483 516	49
12	.494 621	6.40	.977 711	.70	.516 910	7.08	.483 090	48
13	.495 005	6.38	.977 669	.68	.517 335	7.10	.482 665	47
14	.495 388	6.40	.977 628	.70	.517 761	7.08	.482 239	46
15	9.495 772	6.37	9.977 586	.70	9.518 186	7.07	0.481 814	45
16	.496 154	6.38	.977 544	.68	.518 610	7.07	.481 390	44
17	.496 537	6.37	.977 503	.70	.519 034	7.07	.480 966	43
18	.496 919	6.37	.977 461	.70	.519 458	7.07	.480 542	42
19	.497 301	6.35	.977 419	.70	.519 882	7.05	.480 118	41
20	9.497 682	6.37	9.977 377	.70	9.520 305	7.05	0.479 695	40
21	.498 064	6.33	.977 335	.70	.520 728	7.05	.479 272	39
22	.498 444	6.35	.977 293	.70	.521 151	7.03	.478 849	38
23	.498 825	6.32	.977 251	.70	.521 573	7.03	.478 427	37
24	.499 204	6.33	.977 209	.70	.521 995	7.03	.478 005	36
25	9.499 584	6.32	9.977 167	.70	9.522 417	7.02	0.477 583	35
26	.499 963	6.32	.977 125	.70	.522 838	7.02	.477 162	34
27	.500 342	6.32	.977 083	.70	.523 259	7.02	.476 741	33
28	.500 721	6.30	.977 041	.70	.523 680	7.00	.476 320	32
29	.501 099	6.28	.976 999	.70	.524 100	7.00	.475 900	31
30	9.501 476	6.30	9.976 957	.72	9.524 520	7.00	0.475 480	30
31	.501 854	6.28	.976 914	.70	.524 940	6.98	.475 060	29
32	.502 231	6.27	.976 872	.70	.525 359	6.98	.474 641	28
33	.502 607	6.28	.976 830	.72	.525 778	6.98	.474 222	27
34	.502 984	6.27	.976 787	.70	.526 197	6.97	.473 803	26
35	9.503 360	6.25	9.976 745	.72	9.526 615	6.97	0.473 385	25
36	.503 735	6.25	.976 702	.70	.527 033	6.97	.472 967	24
37	.504 110	6.25	.976 660	.72	.527 451	6.95	.472 549	23
38	.504 485	6.25	.976 617	.72	.527 868	6.95	.472 132	22
39	.504 860	6.23	.976 574	.70	.528 285	6.95	.471 715	21
40	9.505 234	6.23	9.976 532	.72	9.528 702	6.95	0.471 298	20
41	.505 608	6.22	.976 489	.72	.529 119	6.93	.470 881	19
42	.505 981	6.22	.976 446	.70	.529 535	6.93	.470 465	18
43	.506 354	6.22	.976 404	.72	.529 951	6.92	.470 049	17
44	.506 727	6.20	.976 361	.72	.530 366	6.92	.469 634	16
45	9.507 099	6.20	9.976 318	.72	9.530 781	6.92	0.469 219	15
46	.507 471	6.20	.976 275	.72	.531 196	6.92	.468 804	14
47	.507 843	6.18	.976 232	.72	.531 611	6.90	.468 389	13
48	.508 214	6.18	.976 189	.72	.532 025	6.90	.467 975	12
49	.508 585	6.18	.976 146	.72	.532 439	6.90	.467 561	11
50	9.508 956	6.17	9.976 103	.72	9.532 853	6.88	0.467 147	10
51	.509 326	6.17	.976 060	.72	.533 266	6.88	.466 734	9
52	.509 696	6.15	.976 017	.72	.533 679	6.88	.466 321	8
53	.510 065	6.15	.975 974	.73	.534 092	6.87	.465 908	7
54	.510 434	6.15	.975 930	.72	.534 504	6.87	.465 496	6
55	9.510 803	6.15	9.975 887	.72	9.534 916	6.87	0.465 084	5
56	.511 172	6.13	.975 844	.73	.535 328	6.85	.464 672	4
57	.511 540	6.12	.975 800	.72	.535 739	6.85	.464 261	3
58	.511 907	6.13	.975 757	.72	.536 150	6.85	.463 850	2
59	.512 275	6.12	.975 714	.73	.536 561	6.85	.463 439	1
60	9.512 642		9.975 670		9.536 972		0.463 028	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

71°

19°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.512 642	6.12	9.975 670	.72	9.536 972	6.83	0.463 028	60
1	·513 009	6.10	·975 627	.73	·537 382	6.83	·462 618	59
2	·513 375	6.10	·975 583	.73	·537 792	6.83	·462 208	58
3	·513 741	6.10	·975 539	.72	·538 202	6.82	·461 798	57
4	·514 107	6.08	·975 496	.73	·538 611	6.82	·461 389	56
5	9.514 472	6.08	9.975 452	.73	9.539 020	6.82	0.460 980	55
6	·514 837	6.08	·975 408	.72	·539 429	6.80	·460 571	54
7	·515 202	6.07	·975 365	.73	·539 837	6.80	·460 163	53
8	·515 566	6.07	·975 321	.73	·540 245	6.80	·459 755	52
9	·515 930	6.07	·975 277	.73	·540 653	6.80	·459 347	51
10	9.516 294	6.05	9.975 233	.73	9.541 061	6.78	0.458 939	50
11	·516 657	6.05	·975 189	.73	·541 468	6.78	·458 532	49
12	·517 020	6.03	·975 145	.73	·541 875	6.77	·458 125	48
13	·517 382	6.05	·975 101	.73	·542 281	6.78	·457 719	47
14	·517 745	6.03	·975 057	.73	·542 688	6.77	·457 312	46
15	9.518 107	6.02	9.975 013	.73	9.543 094	6.75	0.456 906	45
16	·518 468	6.02	·974 969	.73	·543 499	6.77	·456 501	44
17	·518 829	6.02	·974 925	.75	·543 905	6.75	·456 095	43
18	·519 190	6.02	·974 880	.73	·544 310	6.75	·455 690	42
19	·519 551	6.00	·974 836	.73	·544 715	6.73	·455 285	41
20	9.519 911	6.00	9.974 792	.73	9.545 119	6.75	0.454 881	40
21	·520 271	6.00	·974 748	.75	·545 524	6.73	·454 476	39
22	·520 631	5.98	·974 703	.73	·545 928	6.72	·454 072	38
23	·520 990	5.98	·974 659	.75	·546 331	6.73	·453 669	37
24	·521 349	5.97	·974 614	.73	·546 735	6.72	·453 265	36
25	9.521 707	5.98	9.974 570	.75	9.547 138	6.70	0.452 862	35
26	·522 066	5.97	·974 525	.73	·547 540	6.72	·452 460	34
27	·522 424	5.95	·974 481	.75	·547 943	6.70	·452 057	33
28	·522 781	5.95	·974 436	.75	·548 345	6.70	·451 655	32
29	·523 138	5.95	·974 391	.73	·548 747	6.70	·451 253	31
30	9.523 495	5.95	9.974 347	.75	9.549 149	6.68	0.450 851	30
31	·523 852	5.93	·974 302	.75	·549 550	6.68	·450 450	29
32	·524 208	5.93	·974 257	.75	·549 951	6.68	·450 049	28
33	·524 564	5.93	·974 212	.75	·550 352	6.67	·449 648	27
34	·524 920	5.92	·974 167	.75	·550 752	6.68	·449 248	26
35	9.525 275	5.92	9.974 122	.75	9.551 153	6.65	0.448 847	25
36	·525 630	5.90	·974 077	.75	·551 552	6.67	·448 448	24
37	·525 984	5.92	·974 032	.75	·551 952	6.65	·448 048	23
38	·526 339	5.90	·973 987	.75	·552 351	6.65	·447 649	22
39	·526 693	5.88	·973 942	.75	·552 750	6.65	·447 250	21
40	9.527 046	5.90	9.973 897	.75	9.553 149	6.65	0.446 851	20
41	·527 400	5.88	·973 852	.75	·553 548	6.63	·446 452	19
42	·527 753	5.87	·973 807	.77	·553 946	6.63	·446 054	18
43	·528 105	5.88	·973 761	.75	·554 344	6.62	·445 656	17
44	·528 458	5.87	·973 716	.75	·554 741	6.63	·445 259	16
45	9.528 810	5.85	9.973 671	.77	9.555 139	6.62	0.444 861	15
46	·529 161	5.87	·973 625	.75	·555 536	6.62	·444 464	14
47	·529 513	5.85	·973 580	.75	·555 933	6.60	·444 067	13
48	·529 864	5.85	·973 535	.77	·556 329	6.60	·443 671	12
49	·530 215	5.83	·973 489	.75	·556 725	6.60	·443 275	11
50	9.530 565	5.83	9.973 444	.77	9.557 121	6.60	0.442 879	10
51	·530 915	5.83	·973 398	.77	·557 517	6.60	·442 483	9
52	·531 265	5.82	·973 352	.75	·557 913	6.58	·442 087	8
53	·531 614	5.82	·973 307	.77	·558 308	6.58	·441 692	7
54	·531 963	5.82	·973 261	.77	·558 703	6.57	·441 297	6
55	9.532 312	5.82	9.973 215	.77	9.559 097	6.57	0.440 903	5
56	·532 661	5.80	·973 169	.75	·559 491	6.57	·440 509	4
57	·533 009	5.80	·973 124	.77	·559 885	6.57	·440 115	3
58	·533 357	5.78	·973 078	.77	·560 279	6.57	·439 721	2
59	·533 704	5.80	·973 032	.77	·560 673	6.55	·439 327	1
60	9.534 052		9.972 986		9.561 066		0.438 934	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

70°

20°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.534 052	5.78	9.972 986	.77	9.561 066	6.55	0.438 934	60
1	.534 399	5.77	.972 940	.77	.561 459	6.53	.438 541	59
2	.534 745	5.78	.972 894	.77	.561 851	6.55	.438 149	58
3	.535 092	5.77	.972 848	.77	.562 244	6.53	.437 756	57
4	.535 438	5.75	.972 802	.78	.562 636	6.53	.437 364	56
5	9.535 783	5.77	9.972 755	.77	9.563 028	6.52	0.436 972	55
6	.536 129	5.75	.972 709	.77	.563 419	6.53	.436 581	54
7	.536 474	5.73	.972 663	.77	.563 811	6.52	.436 189	53
8	.536 818	5.75	.972 617	.78	.564 202	6.52	.435 798	52
9	.537 163	5.73	.972 570	.77	.564 593	6.50	.435 407	51
10	9.537 507	5.73	9.972 524	.77	9.564 983	6.50	0.435 017	50
11	.537 851	5.72	.972 478	.78	.565 373	6.50	.434 627	49
12	.538 194	5.73	.972 431	.77	.565 763	6.50	.434 237	48
13	.538 538	5.70	.972 385	.78	.566 153	6.48	.433 847	47
14	.538 880	5.72	.972 338	.78	.566 542	6.50	.433 458	46
15	9.539 223	5.70	9.972 291	.77	9.566 932	6.47	0.433 068	45
16	.539 565	5.70	.972 245	.78	.567 320	6.48	.432 680	44
17	.539 907	5.70	.972 198	.78	.567 709	6.48	.432 291	43
18	.540 249	5.68	.972 151	.77	.568 098	6.47	431 902	42
19	.540 590	5.68	.972 105	.78	.568 486	6.45	.431 514	41
20	9.540 931	5.68	9.972 058	.78	9.568 873	6.47	0.431 127	40
21	.541 272	5.68	.972 011	.78	.569 261	6.45	.430 739	39
22	.541 613	5.67	.971 964	.78	.569 648	6.45	.430 352	38
23	.541 953	5.67	.971 917	.78	.570 035	6.45	.429 965	37
24	.542 293	5.65	.971 870	.78	.570 422	6.45	.429 578	36
25	9.542 632	5.65	9.971 823	.78	9.570 809	6.43	0.429 191	35
26	.542 971	5.65	.971 776	.78	.571 195	6.43	.428 805	34
27	.543 310	5.65	.971 729	.78	.571 581	6.43	.428 419	33
28	.543 649	5.63	.971 682	.78	.571 967	6.42	.428 033	32
29	.543 987	5.63	.971 635	.78	.572 352	6.43	.427 648	31
30	9.544 325	5.63	9.971 588	.80	9.572 738	6.42	0.427 262	30
31	.544 663	5.62	.971 540	.78	.573 123	6.40	.426 877	29
32	.545 000	5.63	.971 493	.78	.573 507	6.42	.426 493	28
33	.545 338	5.60	.971 446	.80	.573 892	6.40	.426 108	27
34	.545 674	5.62	.971 398	.78	.574 276	6.40	.425 724	26
35	9.546 011	5.60	9.971 351	.80	9.574 660	6.40	0.425 340	25
36	.546 347	5.60	.971 303	.78	.575 044	6.38	.424 956	24
37	.546 683	5.60	.971 256	.80	.575 427	6.38	.424 573	23
38	.547 019	5.58	.971 208	.78	.575 810	6.38	.424 190	22
39	.547 354	5.58	.971 161	.80	.576 193	6.38	.423 807	21
40	9.547 689	5.58	9.971 113	.78	9.576 576	6.38	0.423 424	20
41	.548 024	5.58	.971 066	.80	.576 959	6.37	.423 041	19
42	.548 359	5.57	.971 018	.80	.577 341	6.37	.422 659	18
43	.548 693	5.57	.970 970	.80	.577 723	6.35	.422 277	17
44	.549 027	5.55	.970 922	.80	.578 104	6.37	.421 896	16
45	9.549 360	5.55	9.970 874	.78	9.578 486	6.35	0.421 514	15
46	.549 693	5.55	.970 827	.80	.578 867	6.35	.421 133	14
47	.550 026	5.55	.970 779	.80	.579 248	6.35	.420 752	13
48	.550 359	5.55	.970 731	.80	.579 629	6.33	.420 371	12
49	.550 692	5.53	.970 683	.80	.580 009	6.33	.419 991	11
50	9.551 024	5.53	9.970 635	.82	9.580 389	6.33	0.419 611	10
51	.551 356	5.52	.970 586	.80	.580 769	6.33	.419 231	9
52	.551 687	5.52	.970 538	.80	.581 149	6.32	.418 851	8
53	.552 018	5.52	.970 490	.80	.581 528	6.32	.418 472	7
54	.552 349	5.52	.970 442	.80	.581 907	6.32	.418 093	6
55	9.552 680	5.50	9.970 394	.82	9.582 286	6.32	0.417 714	5
56	.553 010	5.52	.970 345	.80	.582 665	6.32	.417 335	4
57	.553 341	5.48	.970 297	.80	.583 044	6.30	.416 956	3
58	.553 670	5.50	.970 249	.82	.583 422	6.30	.416 578	2
59	.554 000	5.48	.970 200	.80	.583 800	6.28	.416 200	1
60	9.554 329		9.970 152		9.584 177		0.415 823	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

69°

21°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.554 329	5.48	9.970 152	.82	9.584 177	6.30	0.415 823	60
1	.554 658	5.48	.970 103	.80	.584 555	6.28	.415 445	59
2	.554 987	5.47	.970 055	.82	.584 932	6.28	.415 068	58
3	.555 315	5.47	.970 006	.82	.585 309	6.28	.414 691	57
4	.555 643	5.47	.969 957	.80	.585 686	6.27	.414 314	56
5	9.555 971	5.47	9.969 909	.82	9.586 062	6.28	0.413 938	55
6	.556 299	5.45	.969 860	.82	.586 439	6.27	.413 561	54
7	.556 626	5.45	.969 811	.82	.586 815	6.25	.413 185	53
8	.556 953	5.45	.969 762	.80	.587 190	6.27	.412 810	52
9	.557 280	5.43	.969 714	.82	.587 566	6.25	.412 434	51
10	9.557 606	5.43	9.969 665	.82	9.587 941	6.25	0.412 059	50
11	.557 932	5.43	.969 616	.82	.588 316	6.25	.411 684	49
12	.558 258	5.42	.969 567	.82	.588 691	6.25	.411 309	48
13	.558 583	5.43	.969 518	.82	.589 066	6.23	.410 934	47
14	.558 909	5.42	.969 469	.82	.589 440	6.23	.410 560	46
15	9.559 234	5.40	9.969 420	.83	9.589 814	6.23	0.410 186	45
16	.559 558	5.42	.969 370	.82	.590 188	6.23	.409 812	44
17	.559 883	5.40	.969 321	.82	.590 562	6.22	.409 438	43
18	.560 207	5.40	.969 272	.82	.590 935	6.22	.409 065	42
19	.560 531	5.40	.969 223	.83	.591 308	6.22	.408 692	41
20	9.560 855	5.38	9.969 173	.82	9.591 681	6.22	0.408 319	40
21	.561 178	5.38	.969 124	.82	.592 054	6.20	.407 946	39
22	.561 501	5.38	.969 075	.83	.592 426	6.22	.407 574	38
23	.561 824	5.37	.969 025	.82	.592 799	6.20	.407 201	37
24	.562 146	5.37	.968 976	.83	.593 171	6.18	.406 829	36
25	9.562 468	5.37	9.968 926	.82	9.593 542	6.20	0.406 458	35
26	.562 790	5.37	.968 877	.83	.593 914	6.18	.406 086	34
27	.563 112	5.35	.968 827	.83	.594 285	6.18	.405 715	33
28	.563 433	5.37	.968 777	.82	.594 656	6.18	.405 344	32
29	.563 755	5.33	.968 728	.83	.595 027	6.18	.404 973	31
30	9.564 075	5.35	9.968 678	.83	9.595 398	6.17	0.404 602	30
31	.564 396	5.33	.968 628	.83	.595 768	6.17	.404 232	29
32	.564 716	5.33	.968 578	.83	.596 138	6.17	.403 862	28
33	.565 036	5.33	.968 528	.82	.596 508	6.17	.403 492	27
34	.565 356	5.33	.968 479	.83	.596 878	6.15	.403 122	26
35	9.565 676	5.32	9.968 429	.83	9.597 247	6.15	0.402 753	25
36	.565 995	5.32	.968 379	.83	.597 616	6.15	.402 384	24
37	.566 314	5.30	.968 329	.85	.597 985	6.15	.402 015	23
38	.566 632	5.32	.968 278	.83	.598 354	6.13	.401 646	22
39	.566 951	5.30	.968 228	.83	.598 722	6.15	.401 278	21
40	9.567 269	5.30	9.968 178	.83	9.599 091	6.13	0.400 909	20
41	.567 587	5.28	.968 128	.83	.599 459	6.13	.400 541	19
42	.567 904	5.30	.968 078	.85	.599 827	6.12	.400 173	18
43	.568 222	5.28	.968 027	.83	.600 194	6.13	.399 806	17
44	.568 539	5.28	.967 977	.83	.600 562	6.12	.399 438	16
45	9.568 856	5.27	9.967 927	.85	9.600 929	6.12	0.399 071	15
46	.569 172	5.27	.967 876	.83	.601 296	6.12	.398 704	14
47	.569 488	5.27	.967 826	.85	.601 663	6.10	.398 337	13
48	.569 804	5.27	.967 775	.83	.602 029	6.10	.397 971	12
49	.570 120	5.25	.967 725	.85	.602 395	6.10	.397 605	11
50	9.570 435	5.27	9.967 674	.83	9.602 761	6.10	0.397 239	10
51	.570 751	5.25	.967 624	.85	.603 127	6.10	.396 873	9
52	.571 066	5.23	.967 573	.85	.603 493	6.08	.396 507	8
53	.571 380	5.25	.967 522	.85	.603 858	6.08	.396 142	7
54	.571 695	5.23	.967 471	.83	.604 223	6.08	.395 777	6
55	9.572 009	5.23	9.967 421	.85	9.604 588	6.08	0.395 412	5
56	.572 323	5.22	.967 370	.85	.604 953	6.07	.395 047	4
57	.572 636	5.23	.967 319	.85	.605 317	6.08	.394 683	3
58	.572 950	5.22	.967 268	.85	.605 682	6.07	.394 318	2
59	.573 263	5.20	.967 217	.85	.606 046	6.07	.393 954	1
60	9.573 575		9.967 166		9.606 410		0.393 590	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

68°

22°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.573 575	5.22	9.967 166	.85	9.606 410	6.05	0.393 590	60
1	.573 888	5.20	.967 115	.85	.606 773	6.07	.393 227	59
2	.574 200	5.20	.967 064	.85	.607 137	6.05	.392 863	58
3	.574 512	5.20	.967 013	.87	.607 500	6.05	.392 500	57
4	.574 824	5.20	.966 961	.85	.607 863	6.03	.392 137	56
5	9.575 136	5.18	9.966 910	.85	9.608 225	6.05	0.391 775	55
6	.575 447	5.18	.966 859	.85	.608 588	6.03	.391 412	54
7	.575 758	5.18	.966 808	.87	.608 950	6.03	.391 050	53
8	.576 069	5.17	.966 756	.85	.609 312	6.03	.390 688	52
9	.576 379	5.17	.966 705	.87	.609 674	6.03	.390 326	51
10	9.576 689	5.17	9.966 653	.85	9.610 036	6.02	0.389 964	50
11	.576 999	5.17	.966 602	.87	.610 397	6.03	.389 603	49
12	.577 309	5.15	.966 550	.85	.610 759	6.02	.389 241	48
13	.577 618	5.15	.966 499	.87	.611 120	6.00	.388 880	47
14	.577 927	5.15	.966 447	.87	.611 480	6.02	.388 520	46
15	9.578 236	5.15	9.966 395	.85	9.611 841	6.00	0.388 159	45
16	.578 545	5.13	.966 344	.87	.612 201	6.00	.387 799	44
17	.578 853	5.15	.966 292	.87	.612 561	6.00	.387 439	43
18	.579 162	5.13	.966 240	.87	.612 921	6.00	.387 079	42
19	.579 470	5.12	.966 188	.87	.613 281	6.00	.386 719	41
20	9.579 777	5.13	9.966 136	.85	9.613 641	5.98	0.386 359	40
21	.580 085	5.12	.966 085	.87	.614 000	5.98	.386 000	39
22	.580 392	5.12	.966 033	.87	.614 359	5.98	.385 641	38
23	.580 699	5.10	.965 981	.87	.614 718	5.98	.385 282	37
24	.581 005	5.12	.965 929	.88	.615 077	5.97	.384 923	36
25	9.581 312	5.10	9.965 876	.87	9.615 435	5.97	0.384 565	35
26	.581 618	5.10	.965 824	.87	.615 793	5.97	.384 207	34
27	.581 924	5.08	.965 772	.87	.616 151	5.97	.383 849	33
28	.582 229	5.10	.965 720	.87	.616 509	5.97	.383 491	32
29	.582 535	5.08	.965 668	.88	.616 867	5.95	.383 133	31
30	9.582 840	5.08	9.965 615	.87	9.617 224	5.97	0.382 776	30
31	.583 145	5.07	.965 563	.87	.617 582	5.95	.382 418	29
32	.583 449	5.08	.965 511	.88	.617 939	5.93	.382 061	28
33	.583 754	5.07	.965 458	.87	.618 295	5.95	.381 705	27
34	.584 058	5.05	.965 406	.88	.618 652	5.93	.381 348	26
35	9.584 361	5.07	9.965 353	.87	9.619 008	5.93	0.380 992	25
36	.584 665	5.05	.965 301	.88	.619 364	5.93	.380 636	24
37	.584 968	5.07	.965 248	.88	.619 720	5.93	.380 280	23
38	.585 272	5.03	.965 195	.87	.620 076	5.93	.379 924	22
39	.585 574	5.05	.965 143	.88	.620 432	5.92	.379 568	21
40	9.585 877	5.03	9.965 090	.88	9.620 787	5.92	0.379 213	20
41	.586 179	5.05	.965 037	.88	.621 142	5.92	.378 858	19
42	.586 482	5.02	.964 984	.88	.621 497	5.92	.378 503	18
43	.586 783	5.03	.964 931	.87	.621 852	5.92	.378 148	17
44	.587 085	5.02	.964 879	.88	.622 207	5.90	.377 793	16
45	9.587 386	5.03	9.964 826	.88	9.622 561	5.90	0.377 439	15
46	.587 688	5.02	.964 773	.88	.622 915	5.90	.377 085	14
47	.587 989	5.00	.964 720	.90	.623 269	5.90	.376 731	13
48	.588 289	5.02	.964 666	.88	.623 623	5.88	.376 377	12
49	.588 590	5.00	.964 613	.88	.623 976	5.90	.376 024	11
50	9.588 890	5.00	9.964 560	.88	9.624 330	5.88	0.375 670	10
51	.589 190	4.98	.964 507	.88	.624 683	5.88	.375 317	9
52	.589 489	5.00	.964 454	.90	.625 036	5.87	.374 964	8
53	.589 789	4.98	.964 400	.88	.625 388	5.88	.374 612	7
54	.590 088	4.98	.964 347	.88	.625 741	5.87	.374 259	6
55	9.590 387	4.98	9.964 294	.90	9.626 093	5.87	0.373 907	5
56	.590 686	4.97	.964 240	.88	.626 445	5.87	.373 555	4
57	.590 984	4.97	.964 187	.90	.626 797	5.87	.373 203	3
58	.591 282	4.97	.964 133	.88	.627 149	5.87	.372 851	2
59	.591 580	4.97	.964 080	.90	.627 501	5.85	.372 499	1
60	9.591 878		9.964 026		9.627 852		0.372 148	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

67°

23°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.591 878	4.97	9.964 026	.90	9.627 852	5.85	0.372 148	60
1	.592 176	4.95	.963 972	.88	.628 203	5.85	.371 797	59
2	.592 473	4.95	.963 919	.90	.628 554	5.85	.371 446	58
3	.592 770	4.95	.963 865	.90	.628 905	5.83	.371 095	57
4	.593 067	4.93	.963 811	.90	.629 255	5.85	.370 745	56
5	9.593 363	4.93	9.963 757	.88	9.629 606	5.83	0.370 394	55
6	.593 659	4.93	.963 704	.90	.629 956	5.83	.370 044	54
7	.593 955	4.93	.963 650	.90	.630 306	5.83	.369 694	53
8	.594 251	4.93	.963 596	.90	.630 656	5.82	.369 344	52
9	.594 547	4.92	.963 542	.90	.631 005	5.83	.368 995	51
10	9.594 842	4.92	9.963 488	.90	9.631 355	5.82	0.368 645	50
11	.595 137	4.92	.963 434	.92	.631 704	5.82	.368 296	49
12	.595 432	4.92	.963 379	.90	.632 053	5.82	.367 947	48
13	.595 727	4.90	.963 325	.90	.632 402	5.80	.367 598	47
14	.596 021	4.90	.963 271	.90	.632 750	5.82	.367 250	46
15	9.596 315	4.90	9.963 217	.90	9.633 099	5.80	0.366 901	45
16	.596 609	4.90	.963 163	.92	.633 447	5.80	.366 553	44
17	.596 903	4.88	.963 108	.90	.633 795	5.80	.366 205	43
18	.597 196	4.90	.963 054	.92	.634 143	5.78	.365 857	42
19	.597 490	4.88	.962 999	.90	.634 490	5.80	.365 510	41
20	9.597 783	4.87	9.962 945	.92	9.634 838	5.78	0.365 162	40
21	.598 075	4.88	.962 890	.90	.635 185	5.78	.364 815	39
22	.598 368	4.87	.962 836	.92	.635 532	5.78	.364 468	38
23	.598 660	4.87	.962 781	.90	.635 879	5.78	.364 121	37
24	.598 952	4.87	.962 727	.92	.636 226	5.77	.363 774	36
25	9.599 244	4.87	9.962 672	.92	9.636 572	5.78	0.363 428	35
26	.599 536	4.85	.962 617	.92	.636 919	5.77	.363 081	34
27	.599 827	4.85	.962 562	.90	.637 265	5.77	.362 735	33
28	.600 118	4.85	.962 508	.92	.637 611	5.75	.362 389	32
29	.600 409	4.85	.962 453	.92	.637 956	5.77	.362 044	31
30	9.600 700	4.83	9.962 398	.92	9.638 302	5.75	0.361 698	30
31	.600 990	4.83	.962 343	.92	.638 647	5.75	.361 353	29
32	.601 280	4.83	.962 288	.92	.638 992	5.75	.361 008	28
33	.601 570	4.83	.962 233	.92	.639 337	5.75	.360 663	27
34	.601 860	4.83	.962 178	.92	.639 682	5.75	.360 318	26
35	9.602 150	4.82	9.962 123	.93	9.640 027	5.73	0.359 973	25
36	.602 439	4.82	.962 067	.92	.640 371	5.75	.359 629	24
37	.602 728	4.82	.962 012	.92	.640 716	5.73	.359 284	23
38	.603 017	4.80	.961 957	.92	.641 060	5.73	.358 940	22
39	.603 305	4.82	.961 902	.93	.641 404	5.72	.358 596	21
40	9.603 594	4.80	9.961 846	.92	9.641 747	5.73	0.358 253	20
41	.603 882	4.80	.961 791	.93	.642 091	5.72	.357 909	19
42	.604 170	4.78	.961 735	.92	.642 434	5.72	.357 566	18
43	.604 457	4.80	.961 680	.93	.642 777	5.72	.357 223	17
44	.604 745	4.78	.961 624	.92	.643 120	5.72	.356 880	16
45	9.605 032	4.78	9.961 569	.93	9.643 463	5.72	0.356 537	15
46	.605 319	4.78	.961 513	.92	.643 806	5.70	.356 194	14
47	.605 606	4.77	.961 458	.93	.644 148	5.70	.355 852	13
48	.605 892	4.78	.961 402	.93	.644 490	5.70	.355 510	12
49	.606 179	4.77	.961 346	.93	.644 832	5.70	.355 168	11
50	9.606 465	4.77	9.961 290	.92	9.645 174	5.70	0.354 826	10
51	.606 751	4.75	.961 235	.93	.645 516	5.68	.354 484	9
52	.607 036	4.77	.961 179	.93	.645 857	5.70	.354 143	8
53	.607 322	4.75	.961 123	.93	.646 199	5.68	.353 801	7
54	.607 607	4.75	.961 067	.93	.646 540	5.68	.353 460	6
55	9.607 892	4.75	9.961 011	.93	9.646 881	5.68	0.353 119	5
56	.608 177	4.73	.960 955	.93	.647 222	5.67	.352 778	4
57	.608 461	4.73	.960 899	.93	.647 562	5.68	.352 438	3
58	.608 745	4.73	.960 843	.95	.647 903	5.67	.352 097	2
59	.609 029	4.73	.960 786	.93	.648 243	5.67	.351 757	1
60	9.609 313		9.960 730		9.648 583		0.351 417	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

66°

24°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.609 313	4.73	9.960 730	.93	9.648 583	5.67	0.351 417	60
1	.609 597	4.72	.960 674	.93	.648 923	5.67	.351 077	59
2	.609 880	4.73	.960 618	.95	.649 263	5.65	.350 737	58
3	.610 164	4.72	.960 561	.93	.649 602	5.67	.350 398	57
4	.610 447	4.70	.960 505	.95	.649 942	5.65	.350 058	56
5	9.610 729	4.72	9.960 448	.93	9.650 281	5.65	0.349 719	55
6	.611 012	4.70	.960 392	.95	.650 620	5.65	.349 380	54
7	.611 294	4.70	.960 335	.93	.650 959	5.63	.349 041	53
8	.611 576	4.70	.960 279	.95	.651 297	5.65	.348 703	52
9	.611 858	4.70	.960 222	.95	.651 636	5.63	.348 364	51
10	9.612 140	4.68	9.960 165	.93	9.651 974	5.63	0.348 026	50
11	.612 421	4.68	.960 109	.95	.652 312	5.63	.347 688	49
12	.612 702	4.68	.960 052	.95	.652 650	5.63	.347 350	48
13	.612 983	4.68	.959 995	.95	.652 988	5.63	.347 012	47
14	.613 264	4.68	.959 938	.93	.653 326	5.62	.346 674	46
15	9.613 545	4.67	9.959 882	.95	9.653 663	5.62	0.346 337	45
16	.613 825	4.67	.959 825	.95	.654 000	5.62	.346 000	44
17	.614 105	4.67	.959 768	.95	.654 337	5.62	.345 663	43
18	.614 385	4.67	.959 711	.95	.654 674	5.62	.345 326	42
19	.614 665	4.65	.959 654	.97	.655 011	5.62	.344 989	41
20	9.614 944	4.65	9.959 596	.95	9.655 348	5.60	0.344 652	40
21	.615 223	4.65	.959 539	.95	.655 684	5.60	.344 316	39
22	.615 502	4.65	.959 482	.95	.656 020	5.60	.343 980	38
23	.615 781	4.65	.959 425	.95	.656 356	5.60	.343 644	37
24	.616 060	4.63	.959 368	.97	.656 692	5.60	.343 308	36
25	9.616 338	4.63	9.959 310	.95	9.657 028	5.60	0.342 972	35
26	.616 616	4.63	.959 253	.97	.657 364	5.58	.342 636	34
27	.616 894	4.63	.959 195	.95	.657 699	5.58	.342 301	33
28	.617 172	4.63	.959 138	.97	.658 034	5.58	.341 966	32
29	.617 450	4.62	.959 080	.95	.658 369	5.58	.341 631	31
30	9.617 727	4.62	9.959 023	.97	9.658 704	5.58	0.341 296	30
31	.618 004	4.62	.958 965	.95	.659 039	5.57	.340 961	29
32	.618 281	4.62	.958 908	.97	.659 373	5.58	.340 627	28
33	.618 558	4.60	.958 850	.97	.659 708	5.57	.340 292	27
34	.618 834	4.60	.958 792	.97	.660 042	5.57	.339 958	26
35	9.619 110	4.60	9.958 734	.95	9.660 376	5.57	0.339 624	25
36	.619 386	4.60	.958 677	.97	.660 710	5.55	.339 290	24
37	.619 662	4.60	.958 619	.97	.661 043	5.57	.338 957	23
38	.619 938	4.58	.958 561	.97	.661 377	5.55	.338 623	22
39	.620 213	4.58	.958 503	.97	.661 710	5.55	.338 290	21
40	9.620 488	4.58	9.958 445	.97	9.662 043	5.55	0.337 957	20
41	.620 763	4.58	.958 387	.97	.662 376	5.55	.337 624	19
42	.621 038	4.58	.958 329	.97	.662 709	5.55	.337 291	18
43	.621 313	4.57	.958 271	.97	.663 042	5.55	.336 958	17
44	.621 587	4.57	.958 213	.98	.663 375	5.53	.336 625	16
45	9.621 861	4.57	9.958 154	.97	9.663 707	5.53	0.336 293	15
46	.622 135	4.57	.958 096	.97	.664 039	5.53	.335 961	14
47	.622 409	4.55	.958 038	.98	.664 371	5.53	.335 629	13
48	.622 682	4.57	.957 979	.97	.664 703	5.53	.335 297	12
49	.622 956	4.55	.957 921	.97	.665 035	5.52	.334 965	11
50	9.623 229	4.55	9.957 863	.98	9.665 366	5.53	0.334 634	10
51	.623 502	4.53	.957 804	.97	.665 698	5.52	.334 302	9
52	.623 774	4.55	.957 746	.98	.666 029	5.52	.333 971	8
53	.624 047	4.53	.957 687	.98	.666 360	5.52	.333 640	7
54	.624 319	4.53	.957 628	.97	.666 691	5.50	.333 309	6
55	9.624 591	4.53	9.957 570	.98	9.667 021	5.52	0.332 979	5
56	.624 863	4.53	.957 511	.98	.667 352	5.50	.332 648	4
57	.625 135	4.52	.957 452	.98	.667 682	5.52	.332 318	3
58	.625 406	4.52	.957 393	.97	.668 013	5.50	.331 987	2
59	.625 677	4.52	.957 335	.98	.668 343	5.50	.331 657	1
60	9.625 948		9.957 276		9.668 673		0.331 327	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

65°

25°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.625 948	4.52	9.957 276	.98	9.668 673	5.48	0.331 327	60
1	.626 219	4.52	.957 217	.98	.669 002	5.50	.330 998	59
2	.626 490	4.50	.957 158	.98	.669 332	5.48	.330 668	58
3	.626 760	4.50	.957 099	.98	.669 661	5.50	.330 339	57
4	.627 030	4.50	.957 040	.98	.669 991	5.48	.330 009	56
5	9.627 300	4.50	9.956 981	1.00	9.670 320	5.48	0.329 680	55
6	.627 570	4.50	.956 921	.98	.670 649	5.47	.329 351	54
7	.627 840	4.48	.956 862	.98	.670 977	5.48	.329 023	53
8	.628 109	4.48	.956 803	.98	.671 306	5.48	.328 694	52
9	.628 378	4.48	.956 744	1.00	.671 635	5.47	.328 365	51
10	9.628 647	4.48	9.956 684	.98	9.671 963	5.47	0.328 037	50
11	.628 916	4.48	.956 625	.98	.672 291	5.47	.327 709	49
12	.629 185	4.47	.956 566	1.00	.672 619	5.47	.327 381	48
13	.629 453	4.47	.956 506	.98	.672 947	5.45	.327 053	47
14	.629 721	4.47	.956 447	1.00	.673 274	5.47	.326 726	46
15	9.629 989	4.47	9.956 387	1.00	9.673 602	5.45	0.326 398	45
16	.630 257	4.45	.956 327	.98	.673 929	5.47	.326 071	44
17	.630 524	4.47	.956 268	1.00	.674 257	5.45	.325 743	43
18	.630 792	4.45	.956 208	1.00	.674 584	5.45	.325 416	42
19	.631 059	4.45	.956 148	.98	.674 911	5.43	.325 089	41
20	9.631 326	4.45	9.956 089	1.00	9.675 237	5.45	0.324 763	40
21	.631 593	4.43	.956 029	1.00	.675 564	5.43	.324 436	39
22	.631 859	4.43	.955 969	1.00	.675 890	5.45	.324 110	38
23	.632 125	4.45	.955 909	1.00	.676 217	5.43	.323 783	37
24	.632 392	4.43	.955 849	1.00	.676 543	5.43	.323 457	36
25	9.632 658	4.42	9.955 789	1.00	9.676 869	5.42	0.323 131	35
26	.632 923	4.43	.955 729	1.00	.677 194	5.43	.322 806	34
27	.633 189	4.42	.955 669	1.00	.677 520	5.43	.322 480	33
28	.633 454	4.42	.955 609	1.02	.677 846	5.42	.322 154	32
29	.633 719	4.42	.955 548	1.00	.678 171	5.42	.321 829	31
30	9.633 984	4.42	9.955 488	1.00	9.678 496	5.42	0.321 504	30
31	.634 249	4.42	.955 428	1.00	.678 821	5.42	.321 179	29
32	.634 514	4.40	.955 368	1.02	.679 146	5.42	.320 854	28
33	.634 778	4.40	.955 307	1.00	.679 471	5.40	.320 529	27
34	.635 042	4.40	.955 247	1.02	.679 795	5.42	.320 205	26
35	9.635 306	4.40	9.955 186	1.00	9.680 120	5.40	0.319 880	25
36	.635 570	4.40	.955 126	1.02	.680 444	5.40	.319 556	24
37	.635 834	4.38	.955 065	1.00	.680 768	5.40	.319 232	23
38	.636 097	4.38	.955 005	1.02	.681 092	5.40	.318 908	22
39	.636 360	4.38	.954 944	1.02	.681 416	5.40	.318 584	21
40	9.636 623	4.38	9.954 883	1.00	9.681 740	5.38	0.318 260	20
41	.636 886	4.37	.954 823	1.02	.682 063	5.40	.317 937	19
42	.637 148	4.38	.954 762	1.02	.682 387	5.38	.317 613	18
43	.637 411	4.37	.954 701	1.02	.682 710	5.38	.317 290	17
44	.637 673	4.37	.954 640	1.02	.683 033	5.38	.316 967	16
45	9.637 935	4.37	9.954 579	1.02	9.683 356	5.38	0.316 644	15
46	.638 197	4.35	.954 518	1.02	.683 679	5.37	.316 321	14
47	.638 458	4.37	.954 457	1.02	.684 001	5.38	.315 999	13
48	.638 720	4.35	.954 396	1.02	.684 324	5.37	.315 676	12
49	.638 981	4.35	.954 335	1.02	.684 646	5.37	.315 354	11
50	9.639 242	4.35	9.954 274	1.02	9.684 968	5.37	0.315 032	10
51	.639 503	4.35	.954 213	1.02	.685 290	5.37	.314 710	9
52	.639 764	4.33	.954 152	1.03	.685 612	5.37	.314 388	8
53	.640 024	4.33	.954 090	1.02	.685 934	5.35	.314 066	7
54	.640 284	4.33	.954 029	1.02	.686 255	5.37	.313 745	6
55	9.640 544	4.33	9.953 968	1.03	9.686 577	5.35	0.313 423	5
56	.640 804	4.33	.953 906	1.02	.686 898	5.35	.313 102	4
57	.641 064	4.33	.953 845	1.03	.687 219	5.35	.312 781	3
58	.641 324	4.32	.953 783	1.02	.687 540	5.35	.312 460	2
59	.641 583	4.32	.953 722	1.03	.687 861	5.35	.312 139	1
60	9.641 842		9.953 660		9.688 182		0.311 818	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

64°

26°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.641 842	4.32	9.953 660	1.02	9.688 182	5.33	0.311 818	60
1	.642 101	4.32	.953 599	1.03	.688 502	5.35	.311 498	59
2	.642 360	4.30	.953 537	1.03	.688 823	5.33	.311 177	58
3	.642 618	4.32	.953 475	1.03	.689 143	5.33	.310 857	57
4	.642 877	4.30	.953 413	1.02	.689 463	5.33	.310 537	56
5	9.643 135	4.30	9.953 352	1.03	9.689 783	5.33	0.310 217	55
6	.643 393	4.28	.953 290	1.03	.690 103	5.33	.309 897	54
7	.643 650	4.30	.953 228	1.03	.690 423	5.32	.309 577	53
8	.643 908	4.28	.953 166	1.03	.690 742	5.33	.309 258	52
9	.644 165	4.30	.953 104	1.03	.691 062	5.32	.308 938	51
10	9.644 423	4.28	9.953 042	1.03	9.691 381	5.32	0.308 619	50
11	.644 680	4.27	.952 980	1.03	.691 700	5.32	.308 300	49
12	.644 936	4.28	.952 918	1.05	.692 019	5.32	.307 981	48
13	.645 193	4.28	.952 855	1.03	.692 338	5.30	.307 662	47
14	.645 450	4.27	.952 793	1.03	.692 656	5.32	.307 344	46
15	9.645 706	4.27	9.952 731	1.03	9.692 975	5.30	0.307 025	45
16	.645 962	4.27	.952 669	1.05	.693 293	5.32	.306 707	44
17	.646 218	4.27	.952 606	1.03	.693 612	5.30	.306 388	43
18	.646 474	4.25	.952 544	1.05	.693 930	5.30	.306 070	42
19	.646 729	4.25	.952 481	1.03	.694 248	5.30	.305 752	41
20	9.646 984	4.27	9.952 419	1.05	9.694 566	5.28	0.305 434	40
21	.647 240	4.23	.952 356	1.03	.694 883	5.30	.305 117	39
22	.647 494	4.25	.952 294	1.05	.695 201	5.28	.304 799	38
23	.647 749	4.25	.952 231	1.05	.695 518	5.30	.304 482	37
24	.648 004	4.23	.952 168	1.03	.695 836	5.28	.304 164	36
25	9.648 258	4.23	9.952 106	1.05	9.696 153	5.28	0.303 847	35
26	.648 512	4.23	.952 043	1.05	.696 470	5.28	.303 530	34
27	.648 766	4.23	.951 980	1.05	.696 787	5.27	.303 213	33
28	.649 020	4.23	.951 917	1.05	.697 103	5.28	.302 897	32
29	.649 274	4.22	.951 854	1.05	.697 420	5.27	.302 580	31
30	9.649 527	4.23	9.951 791	1.05	9.697 736	5.28	0.302 264	30
31	.649 781	4.22	.951 728	1.05	.698 053	5.27	.301 947	29
32	.650 034	4.22	.951 665	1.05	.698 369	5.27	.301 631	28
33	.650 287	4.20	.951 602	1.05	.698 685	5.27	.301 315	27
34	.650 539	4.22	.951 539	1.05	.699 001	5.25	.300 999	26
35	9.650 792	4.20	9.951 476	1.07	9.699 316	5.27	0.300 684	25
36	.651 044	4.22	.951 412	1.05	.699 632	5.25	.300 368	24
37	.651 297	4.20	.951 349	1.05	.699 947	5.27	.300 053	23
38	.651 549	4.18	.951 286	1.07	.700 263	5.25	.299 737	22
39	.651 800	4.20	.951 222	1.05	.700 578	5.25	.299 422	21
40	9.652 052	4.20	9.951 159	1.05	9.700 893	5.25	0.299 107	20
41	.652 304	4.18	.951 096	1.07	.701 208	5.25	.298 792	19
42	.652 555	4.18	.951 032	1.07	.701 523	5.23	.298 477	18
43	.652 806	4.18	.950 968	1.05	.701 837	5.25	.298 163	17
44	.653 057	4.18	.950 905	1.07	.702 152	5.23	.297 848	16
45	9.653 308	4.17	9.950 841	1.05	9.702 466	5.25	0.297 534	15
46	.653 558	4.17	.950 778	1.07	.702 781	5.23	.297 219	14
47	.653 808	4.18	.950 714	1.07	.703 095	5.23	.296 905	13
48	.654 059	4.17	.950 650	1.07	.703 409	5.22	.296 591	12
49	.654 309	4.15	.950 586	1.07	.703 722	5.23	.296 278	11
50	9.654 558	4.17	9.950 522	1.07	9.704 036	5.23	0.295 964	10
51	.654 808	4.17	.950 458	1.07	.704 350	5.22	.295 650	9
52	.655 058	4.15	.950 394	1.07	.704 663	5.22	.295 337	8
53	.655 307	4.15	.950 330	1.07	.704 976	5.23	.295 024	7
54	.655 556	4.15	.950 266	1.07	.705 290	5.22	.294 710	6
55	9.655 805	4.15	9.950 202	1.07	9.705 603	5.22	0.294 397	5
56	.656 054	4.13	.950 138	1.07	.705 916	5.20	.294 084	4
57	.656 302	4.15	.950 074	1.07	.706 228	5.22	.293 772	3
58	.656 551	4.13	.950 010	1.08	.706 541	5.22	.293 459	2
59	.656 799	4.13	.949 945	1.07	.706 854	5.20	.293 146	1
60	9.657 047		9.949 881		9.707 166		0.292 834	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

63°

27°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.657 047	4.13	9.949 881	1.08	9.707 166	5.20	0.292 834	60
1	.657 295	4.12	.949 816	1.07	.707 478	5.20	.292 522	59
2	.657 542	4.13	.949 752	1.07	.707 790	5.20	.292 210	58
3	.657 790	4.12	.949 688	1.08	.708 102	5.20	.291 898	57
4	.658 037	4.12	.949 623	1.08	.708 414	5.20	.291 586	56
5	9.658 284	4.12	9.949 558	1.07	9.708 726	5.18	0.291 274	55
6	.658 531	4.12	.949 494	1.08	.709 037	5.20	.290 963	54
7	.658 778	4.12	.949 429	1.08	.709 349	5.18	.290 651	53
8	.659 025	4.10	.949 364	1.07	.709 660	5.18	.290 340	52
9	.659 271	4.10	.949 300	1.08	.709 971	5.18	.290 029	51
10	9.659 517	4.10	9.949 235	1.08	9.710 282	5.18	0.289 718	50
11	.659 763	4.10	.949 170	1.08	.710 593	5.18	.289 407	49
12	.660 009	4.10	.949 105	1.08	.710 904	5.18	.289 096	48
13	.660 255	4.10	.949 040	1.08	.711 215	5.17	.288 785	47
14	.660 501	4.08	.948 975	1.08	.711 525	5.18	.288 475	46
15	9.660 746	4.08	9.948 910	1.08	9.711 836	5.17	0.288 164	45
16	.660 991	4.08	.948 845	1.08	.712 146	5.17	.287 854	44
17	.661 236	4.08	.948 780	1.08	.712 456	5.17	.287 544	43
18	.661 481	4.08	.948 715	1.08	.712 766	5.17	.287 234	42
19	.661 726	4.07	.948 650	1.10	.713 076	5.17	.286 924	41
20	9.661 970	4.07	9.948 584	1.08	9.713 386	5.17	0.286 614	40
21	.662 214	4.08	.948 519	1.08	.713 696	5.15	.286 304	39
22	.662 459	4.07	.948 454	1.10	.714 005	5.15	.285 995	38
23	.662 703	4.05	.948 388	1.08	.714 314	5.17	.285 686	37
24	.662 946	4.07	.948 323	1.10	.714 624	5.15	.285 376	36
25	9.663 190	4.05	9.948 257	1.08	9.714 933	5.15	0.285 067	35
26	.663 433	4.07	.948 192	1.10	.715 242	5.15	.284 758	34
27	.663 677	4.05	.948 126	1.10	.715 551	5.15	.284 449	33
28	.663 920	4.05	.948 060	1.08	.715 860	5.13	.284 140	32
29	.664 163	4.05	.947 995	1.10	.716 168	5.15	.283 832	31
30	9.664 406	4.03	9.947 929	1.10	9.716 477	5.13	0.283 523	30
31	.664 648	4.05	.947 863	1.10	.716 785	5.13	.283 215	29
32	.664 891	4.03	.947 797	1.10	.717 093	5.13	.282 907	28
33	.665 133	4.03	.947 731	1.10	.717 401	5.13	.282 599	27
34	.665 375	4.03	.947 665	1.08	.717 709	5.13	.282 291	26
35	9.665 617	4.03	9.947 600	1.12	9.718 017	5.13	0.281 983	25
36	.665 859	4.02	.947 533	1.10	.718 325	5.13	.281 675	24
37	.666 100	4.03	.947 467	1.10	.718 633	5.12	.281 367	23
38	.666 342	4.02	.947 401	1.10	.718 940	5.13	.281 060	22
39	.666 583	4.02	.947 335	1.10	.719 248	5.12	.280 752	21
40	9.666 824	4.02	9.947 269	1.10	9.719 555	5.12	0.280 445	20
41	.667 065	4.00	.947 203	1.12	.719 862	5.12	.280 138	19
42	.667 305	4.02	.947 136	1.10	.720 169	5.12	.279 831	18
43	.667 546	4.00	.947 070	1.10	.720 476	5.12	.279 524	17
44	.667 786	4.02	.947 004	1.12	.720 783	5.10	.279 217	16
45	9.668 027	4.00	9.946 937	1.10	9.721 089	5.12	0.278 911	15
46	.668 267	3.98	.946 871	1.12	.721 396	5.10	.278 604	14
47	.668 506	4.00	.946 804	1.10	.721 702	5.12	.278 298	13
48	.668 746	4.00	.946 738	1.12	.722 009	5.10	.277 991	12
49	.668 986	3.98	.946 671	1.12	.722 315	5.10	.277 685	11
50	9.669 225	3.98	9.946 604	1.10	9.722 621	5.10	0.277 379	10
51	.669 464	3.98	.946 538	1.12	.722 927	5.08	.277 073	9
52	.669 703	3.98	.946 471	1.12	.723 232	5.10	.276 768	8
53	.669 942	3.98	.946 404	1.12	.723 538	5.10	.276 462	7
54	.670 181	3.97	.946 337	1.12	.723 844	5.08	.276 156	6
55	9.670 419	3.98	9.946 270	1.12	9.724 149	5.08	0.275 851	5
56	.670 658	3.97	.946 203	1.12	.724 454	5.10	.275 546	4
57	.670 896	3.97	.946 136	1.12	.724 760	5.08	.275 240	3
58	.671 134	3.97	.946 069	1.12	.725 065	5.08	.274 935	2
59	.671 372	3.95	.946 002	1.12	.725 370	5.07	.274 630	1
60	9.671 609		9.945 935		9.725 674		0.274 326	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

62°

28°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.671 609	3.97	9.945 935	1.12	9.725 674	5.08	0.274 326	60
1	.671 847	3.95	.945 868	1.13	.725 979	5.08	.274 021	59
2	.672 084	3.95	.945 800	1.12	.726 284	5.07	.273 716	58
3	.672 321	3.95	.945 733	1.12	.726 588	5.07	.273 412	57
4	.672 558	3.95	.945 666	1.13	.726 892	5.08	.273 108	56
5	9.672 795	3.95	9.945 598	1.12	9.727 197	5.07	0.272 803	55
6	.673 032	3.93	.945 531	1.12	.727 501	5.07	.272 499	54
7	.673 268	3.95	.945 464	1.13	.727 805	5.07	.272 195	53
8	.673 505	3.93	.945 396	1.13	.728 109	5.05	.271 891	52
9	.673 741	3.93	.945 328	1.12	.728 412	5.07	.271 588	51
10	9.673 977	3.93	9.945 261	1.13	9.728 716	5.07	0.271 284	50
11	.674 213	3.92	.945 193	1.13	.729 020	5.05	.270 980	49
12	.674 448	3.93	.945 125	1.12	.729 323	5.05	.270 677	48
13	.674 684	3.92	.945 058	1.13	.729 626	5.05	.270 374	47
14	.674 919	3.93	.944 990	1.13	.729 929	5.07	.270 071	46
15	9.675 155	3.92	9.944 922	1.13	9.730 233	5.03	0.269 767	45
16	.675 390	3.90	.944 854	1.13	.730 535	5.05	.269 465	44
17	.675 624	3.92	.944 786	1.13	.730 838	5.05	.269 162	43
18	.675 859	3.92	.944 718	1.13	.731 141	5.05	.268 859	42
19	.676 094	3.90	.944 650	1.13	.731 444	5.03	.268 556	41
20	9.676 328	3.90	9.944 582	1.13	9.731 746	5.03	0.268 254	40
21	.676 562	3.90	.944 514	1.13	.732 048	5.05	.267 952	39
22	.676 796	3.90	.944 446	1.15	.732 351	5.03	.267 649	38
23	.677 030	3.90	.944 377	1.13	.732 653	5.03	.267 347	37
24	.677 264	3.90	.944 309	1.13	.732 955	5.03	.267 045	36
25	9.677 498	3.88	9.944 241	1.15	9.733 257	5.02	0.266 743	35
26	.677 731	3.88	.944 172	1.13	.733 558	5.03	.266 442	34
27	.677 964	3.88	.944 104	1.13	.733 860	5.03	.266 140	33
28	.678 197	3.88	.944 036	1.15	.734 162	5.02	.265 838	32
29	.678 430	3.88	.943 967	1.13	.734 463	5.02	.265 537	31
30	9.678 663	3.87	9.943 899	1.15	9.734 764	5.03	0.265 236	30
31	.678 895	3.88	.943 830	1.15	.735 066	5.02	.264 934	29
32	.679 128	3.87	.943 761	1.13	.735 367	5.02	.264 633	28
33	.679 360	3.87	.943 693	1.15	.735 668	5.02	.264 332	27
34	.679 592	3.87	.943 624	1.15	.735 969	5.00	.264 031	26
35	9.679 824	3.87	9.943 555	1.15	9.736 269	5.02	0.263 731	25
36	.680 056	3.87	.943 486	1.15	.736 570	5.00	.263 430	24
37	.680 288	3.85	.943 417	1.15	.736 870	5.02	.263 130	23
38	.680 519	3.85	.943 348	1.15	.737 171	5.00	.262 829	22
39	.680 750	3.87	.943 279	1.15	.737 471	5.00	.262 529	21
40	9.680 982	3.85	9.943 210	1.15	9.737 771	5.00	0.262 229	20
41	.681 213	3.83	.943 141	1.15	.738 071	5.00	.261 929	19
42	.681 443	3.85	.943 072	1.15	.738 371	5.00	.261 629	18
43	.681 674	3.85	.943 003	1.15	.738 671	5.00	.261 329	17
44	.681 905	3.83	.942 934	1.17	.738 971	5.00	.261 029	16
45	9.682 135	3.83	9.942 864	1.15	9.739 271	4.98	0.260 729	15
46	.682 365	3.83	.942 795	1.15	.739 570	5.00	.260 430	14
47	.682 595	3.83	.942 726	1.17	.739 870	4.98	.260 130	13
48	.682 825	3.83	.942 656	1.15	.740 169	4.98	.259 831	12
49	.683 055	3.82	.942 587	1.17	.740 468	4.98	.259 532	11
50	9.683 284	3.83	9.942 517	1.15	9.740 767	4.98	0.259 233	10
51	.683 514	3.82	.942 448	1.17	.741 066	4.98	.258 934	9
52	.683 743	3.82	.942 378	1.17	.741 365	4.98	.258 635	8
53	.683 972	3.82	.942 308	1.15	.741 664	4.97	.258 336	7
54	.684 201	3.82	.942 239	1.17	.741 962	4.98	.258 038	6
55	9.684 430	3.80	9.942 169	1.17	9.742 261	4.97	0.257 739	5
56	.684 658	3.82	.942 099	1.17	.742 559	4.98	.257 441	4
57	.684 887	3.80	.942 029	1.17	.742 858	4.97	.257 142	3
58	.685 115	3.80	.941 959	1.17	.743 156	4.97	.256 844	2
59	.685 343	3.80	.941 889	1.17	.743 454	4.97	.256 546	1
60	9.685 571		9.941 819		9.743 752		0.256 248	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

61°

29°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.685 571	3.80	9.941 819	1.17	9.743 752	4.97	0.256 248	60
1	.685 799	3.80	.941 749	1.17	.744 050	4.97	.255 950	59
2	.686 027	3.78	.941 679	1.17	.744 348	4.95	.255 652	58
3	.686 254	3.80	.941 609	1.17	.744 645	4.97	.255 355	57
4	.686 482	3.78	.941 539	1.17	.744 943	4.95	.255 057	56
5	9.686 709	3.78	9.941 469	1.18	9.745 240	4.97	0.254 760	55
6	.686 936	3.78	.941 398	1.17	.745 538	4.95	.254 462	54
7	.687 163	3.77	.941 328	1.17	.745 835	4.95	.254 165	53
8	.687 389	3.78	.941 258	1.18	.746 132	4.95	.253 868	52
9	.687 616	3.78	.941 187	1.17	.746 429	4.95	.253 571	51
10	9.687 843	3.77	9.941 117	1.18	9.746 726	4.95	0.253 274	50
11	.688 069	3.77	.941 046	1.18	.747 023	4.93	.252 977	49
12	.688 295	3.77	.940 975	1.17	.747 319	4.95	.252 681	48
13	.688 521	3.77	.940 905	1.18	.747 616	4.95	.252 384	47
14	.688 747	3.75	.940 834	1.18	.747 913	4.93	.252 087	46
15	9.688 972	3.77	9.940 763	1.17	9.748 209	4.93	0.251 791	45
16	.689 198	3.75	.940 693	1.18	.748 505	4.93	.251 495	44
17	.689 423	3.75	.940 622	1.18	.748 801	4.93	.251 199	43
18	.689 648	3.75	.940 551	1.18	.749 097	4.93	.250 903	42
19	.689 873	3.75	.940 480	1.18	.749 393	4.93	.250 607	41
20	9.690 098	3.75	9.940 409	1.18	9.749 689	4.93	0.250 311	40
21	.690 323	3.75	.940 338	1.18	.749 985	4.93	.250 015	39
22	.690 548	3.73	.940 267	1.18	.750 281	4.92	.249 719	38
23	.690 772	3.73	.940 196	1.18	.750 576	4.93	.249 424	37
24	.690 996	3.73	.940 125	1.18	.750 872	4.92	.249 128	36
25	9.691 220	3.73	9.940 054	1.20	9.751 167	4.92	0.248 833	35
26	.691 444	3.73	.939 982	1.18	.751 462	4.92	.248 538	34
27	.691 668	3.73	.939 911	1.18	.751 757	4.92	.248 243	33
28	.691 892	3.72	.939 840	1.20	.752 052	4.92	.247 948	32
29	.692 115	3.73	.939 768	1.18	.752 347	4.92	.247 653	31
30	9.692 339	3.72	9.939 697	1.20	9.752 642	4.92	0.247 358	30
31	.692 562	3.72	.939 625	1.18	.752 937	4.90	.247 063	29
32	.692 785	3.72	.939 554	1.20	.753 231	4.92	.246 769	28
33	.693 008	3.72	.939 482	1.20	.753 526	4.90	.246 474	27
34	.693 231	3.70	.939 410	1.18	.753 820	4.92	.246 180	26
35	9.693 453	3.72	9.939 339	1.20	9.754 115	4.90	0.245 885	25
36	.693 676	3.70	.939 267	1.20	.754 409	4.90	.245 591	24
37	.693 898	3.70	.939 195	1.20	.754 703	4.90	.245 297	23
38	.694 120	3.70	.939 123	1.18	.754 997	4.90	.245 003	22
39	.694 342	3.70	.939 052	1.20	.755 291	4.90	.244 709	21
40	9.694 564	3.70	9.938 980	1.20	9.755 585	4.88	0.244 415	20
41	.694 786	3.68	.938 908	1.20	.755 878	4.90	.244 122	19
42	.695 007	3.70	.938 836	1.22	.756 172	4.88	.243 828	18
43	.695 229	3.68	.938 763	1.20	.756 465	4.90	.243 535	17
44	.695 450	3.68	.938 691	1.20	.756 759	4.88	.243 241	16
45	9.695 671	3.68	9.938 619	1.20	9.757 052	4.88	0.242 948	15
46	.695 892	3.68	.938 547	1.20	.757 345	4.88	.242 655	14
47	.696 113	3.68	.938 475	1.22	.757 638	4.88	.242 362	13
48	.696 334	3.67	.938 402	1.20	.757 931	4.88	.242 069	12
49	.696 554	3.68	.938 330	1.20	.758 224	4.88	.241 776	11
50	9.696 775	3.67	9.938 258	1.22	9.758 517	4.88	0.241 483	10
51	.696 995	3.67	.938 185	1.20	.758 810	4.87	.241 190	9
52	.697 215	3.67	.938 113	1.22	.759 102	4.88	.240 898	8
53	.697 435	3.65	.938 040	1.22	.759 395	4.87	.240 605	7
54	.697 654	3.67	.937 967	1.20	.759 687	4.87	.240 313	6
55	9.697 874	3.67	9.937 895	1.22	9.759 979	4.88	0.240 021	5
56	.698 094	3.65	.937 822	1.22	.760 272	4.87	.239 728	4
57	.698 313	3.65	.937 749	1.22	.760 564	4.87	.239 436	3
58	.698 532	3.65	.937 676	1.20	.760 856	4.87	.239 144	2
59	.698 751	3.65	.937 604	1.22	.761 148	4.85	.238 852	1
60	9.698 970		9.937 531		9.761 439		0.238 561	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

60°

30°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.698 970	3.65	9.937 531	1.22	9.761 439	4.87	0.238 561	60
1	.699 189	3.63	.937 458	1.22	.761 731	4.87	.238 269	59
2	.699 407	3.65	.937 385	1.22	.762 023	4.85	.237 977	58
3	.699 626	3.63	.937 312	1.23	.762 314	4.87	.237 686	57
4	.699 844	3.63	.937 238	1.22	.762 606	4.85	.237 394	56
5	9.700 062	3.63	9.937 165	1.22	9.762 897	4.85	0.237 103	55
6	.700 280	3.63	.937 092	1.22	.763 188	4.85	.236 812	54
7	.700 498	3.63	.937 019	1.22	.763 479	4.85	.236 521	53
8	.700 716	3.62	.936 946	1.23	.763 770	4.85	.236 230	52
9	.700 933	3.63	.936 872	1.22	.764 061	4.85	.235 939	51
10	9.701 151	3.62	9.936 799	1.23	9.764 352	4.85	0.235 648	50
11	.701 368	3.62	.936 725	1.22	.764 643	4.83	.235 357	49
12	.701 585	3.62	.936 652	1.23	.764 933	4.85	.235 067	48
13	.701 802	3.62	.936 578	1.22	.765 224	4.83	.234 776	47
14	.702 019	3.62	.936 505	1.23	.765 514	4.85	.234 486	46
15	9.702 236	3.60	9.936 431	1.23	9.765 805	4.83	0.234 195	45
16	.702 452	3.62	.936 357	1.22	.766 095	4.83	.233 905	44
17	.702 669	3.60	.936 284	1.23	.766 385	4.83	.233 615	43
18	.702 885	3.60	.936 210	1.23	.766 675	4.83	.233 325	42
19	.703 101	3.60	.936 136	1.23	.766 965	4.83	.233 035	41
20	9.703 317	3.60	9.936 062	1.23	9.767 255	4.83	0.232 745	40
21	.703 533	3.60	.935 988	1.23	.767 545	4.82	.232 455	39
22	.703 749	3.58	.935 914	1.23	.767 834	4.83	.232 166	38
23	.703 964	3.58	.935 840	1.23	.768 124	4.83	.231 876	37
24	.704 179	3.60	.935 766	1.23	.768 414	4.82	.231 586	36
25	9.704 395	3.58	9.935 692	1.23	9.768 703	4.82	0.231 297	35
26	.704 610	3.58	.935 618	1.25	.768 992	4.82	.231 008	34
27	.704 825	3.58	.935 543	1.23	.769 281	4.83	.230 719	33
28	.705 040	3.57	.935 469	1.23	.769 571	4.82	.230 429	32
29	.705 254	3.58	.935 395	1.25	.769 860	4.80	.230 140	31
30	9.705 469	3.57	9.935 320	1.23	9.770 148	4.82	0.229 852	30
31	.705 683	3.58	.935 246	1.25	.770 437	4.82	.229 563	29
32	.705 898	3.57	.935 171	1.23	.770 726	4.82	.229 274	28
33	.706 112	3.57	.935 097	1.25	.771 015	4.80	.228 985	27
34	.706 326	3.55	.935 022	1.23	.771 303	4.82	.228 697	26
35	9.706 539	3.57	9.934 948	1.25	9.771 592	4.80	0.228 408	25
36	.706 753	3.57	.934 873	1.25	.771 880	4.80	.228 120	24
37	.706 967	3.55	.934 798	1.25	.772 168	4.82	.227 832	23
38	.707 180	3.55	.934 723	1.23	.772 457	4.80	.227 543	22
39	.707 393	3.55	.934 649	1.25	.772 745	4.80	.227 255	21
40	9.707 606	3.55	9.934 574	1.25	9.773 033	4.80	0.226 967	20
41	.707 819	3.55	.934 499	1.25	.773 321	4.78	.226 679	19
42	.708 032	3.55	.934 424	1.25	.773 608	4.80	.226 392	18
43	.708 245	3.55	.934 349	1.25	.773 896	4.80	.226 104	17
44	.708 458	3.53	.934 274	1.25	.774 184	4.78	.225 816	16
45	9.708 670	3.53	9.934 199	1.27	9.774 471	4.80	0.225 529	15
46	.708 882	3.53	.934 123	1.25	.774 759	4.78	.225 241	14
47	.709 094	3.53	.934 048	1.25	.775 046	4.78	.224 954	13
48	.709 306	3.53	.933 973	1.25	.775 333	4.80	.224 667	12
49	.709 518	3.53	.933 898	1.27	.775 621	4.78	.224 379	11
50	9.709 730	3.52	9.933 822	1.25	9.775 908	4.78	0.224 092	10
51	.709 941	3.53	.933 747	1.27	.776 195	4.78	.223 805	9
52	.710 153	3.52	.933 671	1.25	.776 482	4.77	.223 518	8
53	.710 364	3.52	.933 596	1.27	.776 768	4.78	.223 232	7
54	.710 575	3.52	.933 520	1.25	.777 055	4.78	.222 945	6
55	9.710 786	3.52	9.933 445	1.27	9.777 342	4.77	0.222 658	5
56	.710 997	3.52	.933 369	1.27	.777 628	4.78	.222 372	4
57	.711 208	3.52	.933 293	1.27	.777 915	4.77	.222 085	3
58	.711 419	3.50	.933 217	1.27	.778 201	4.78	.221 799	2
59	.711 629	3.50	.933 141	1.25	.778 488	4.77	.221 512	1
60	9.711 839		9.933 066		9.778 774		0.221 226	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

59°

31°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.711 839	3.52	9.933 066	1.27	9.778 774	4.77	0.221 226	60
1	.712 050	3.50	.932 990	1.27	.779 060	4.77	.220 940	59
2	.712 260	3.48	.932 914	1.27	.779 346	4.77	.220 654	58
3	.712 469	3.50	.932 838	1.27	.779 632	4.77	.220 368	57
4	.712 679	3.50	.932 762	1.28	.779 918	4.75	.220 082	56
5	9.712 889	3.48	9.932 685	1.27	9.780 203	4.77	0.219 797	55
6	.713 098	3.50	.932 609	1.27	.780 489	4.77	.219 511	54
7	.713 308	3.48	.932 533	1.27	.780 775	4.75	.219 225	53
8	.713 517	3.48	.932 457	1.28	.781 060	4.77	.218 940	52
9	.713 726	3.48	.932 380	1.27	.781 346	4.75	.218 654	51
10	9.713 935	3.48	9.932 304	1.27	9.781 631	4.75	0.218 369	50
11	.714 144	3.47	.932 228	1.28	.781 916	4.75	.218 084	49
12	.714 352	3.48	.932 151	1.27	.782 201	4.75	.217 799	48
13	.714 561	3.47	.932 075	1.28	.782 486	4.75	.217 514	47
14	.714 769	3.48	.931 998	1.28	.782 771	4.75	.217 229	46
15	9.714 978	3.47	9.931 921	1.27	9.783 056	4.75	0.216 944	45
16	.715 186	3.47	.931 845	1.28	.783 341	4.75	.216 659	44
17	.715 394	3.47	.931 768	1.28	.783 626	4.73	.216 374	43
18	.715 602	3.45	.931 691	1.28	.783 910	4.75	.216 090	42
19	.715 809	3.47	.931 614	1.28	.784 195	4.73	.215 805	41
20	9.716 017	3.45	9.931 537	1.28	9.784 479	4.75	0.215 521	40
21	.716 224	3.47	.931 460	1.28	.784 764	4.73	.215 236	39
22	.716 432	3.45	.931 383	1.28	.785 048	4.73	.214 952	38
23	.716 639	3.45	.931 306	1.28	.785 332	4.73	.214 668	37
24	.716 846	3.45	.931 229	1.28	.785 616	4.73	.214 384	36
25	9.717 053	3.43	9.931 152	1.28	9.785 900	4.73	0.214 100	35
26	.717 259	3.45	.931 075	1.28	.786 184	4.73	.213 816	34
27	.717 466	3.45	.930 998	1.28	.786 468	4.73	.213 532	33
28	.717 673	3.43	.930 921	1.30	.786 752	4.73	.213 248	32
29	.717 879	3.43	.930 843	1.28	.787 036	4.72	.212 964	31
30	9.718 085	3.43	9.930 766	1.30	9.787 319	4.73	0.212 681	30
31	.718 291	3.43	.930 688	1.28	.787 603	4.72	.212 397	29
32	.718 497	3.43	.930 611	1.30	.787 886	4.73	.212 114	28
33	.718 703	3.43	.930 533	1.28	.788 170	4.72	.211 830	27
34	.718 909	3.42	.930 456	1.30	.788 453	4.72	.211 547	26
35	9.719 114	3.43	9.930 378	1.30	9.788 736	4.72	0.211 264	25
36	.719 320	3.42	.930 300	1.28	.789 019	4.72	.210 981	24
37	.719 525	3.42	.930 223	1.30	.789 302	4.72	.210 698	23
38	.719 730	3.42	.930 145	1.30	.789 585	4.72	.210 415	22
39	.719 935	3.42	.930 067	1.30	.789 868	4.72	.210 132	21
40	9.720 140	3.42	9.929 989	1.30	9.790 151	4.72	0.209 849	20
41	.720 345	3.40	.929 911	1.30	.790 434	4.70	.209 566	19
42	.720 549	3.42	.929 833	1.30	.790 716	4.72	.209 284	18
43	.720 754	3.40	.929 755	1.30	.790 999	4.70	.209 001	17
44	.720 958	3.40	.929 677	1.30	.791 281	4.70	.208 719	16
45	9.721 162	3.40	9.929 599	1.30	9.791 563	4.72	0.208 437	15
46	.721 366	3.40	.929 521	1.32	.791 846	4.70	.208 154	14
47	.721 570	3.40	.929 442	1.30	.792 128	4.70	.207 872	13
48	.721 774	3.40	.929 364	1.30	.792 410	4.70	.207 590	12
49	.721 978	3.38	.929 286	1.32	.792 692	4.70	.207 308	11
50	9.722 181	3.40	9.929 207	1.30	9.792 974	4.70	0.207 026	10
51	.722 385	3.38	.929 129	1.32	.793 256	4.70	.206 744	9
52	.722 588	3.38	.929 050	1.30	.793 538	4.68	.206 462	8
53	.722 791	3.38	.928 972	1.32	.793 819	4.70	.206 181	7
54	.722 994	3.38	.928 893	1.30	.794 101	4.70	.205 899	6
55	9.723 197	3.38	9.928 815	1.32	9.794 383	4.68	0.205 617	5
56	.723 400	3.38	.928 736	1.32	.794 664	4.70	.205 336	4
57	.723 603	3.37	.928 657	1.32	.794 946	4.68	.205 054	3
58	.723 805	3.37	.928 578	1.32	.795 227	4.68	.204 773	2
59	.724 007	3.38	.928 499	1.32	.795 508	4.68	.204 492	1
60	9.724 210		9.928 420		9.795 789		0.204 211	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

58°

32°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.724 210	3.37	9.928 420	1.30	9.795 789	4.68	0.204 211	60
1	.724 412	3.37	.928 342	1.32	.796 070	4.68	.203 930	59
2	.724 614	3.37	.928 263	1.33	.796 351	4.68	.203 649	58
3	.724 816	3.35	.928 183	1.32	.796 632	4.68	.203 368	57
4	.725 017	3.37	.928 104	1.32	.796 913	4.68	.203 087	56
5	9.725 219	3.35	9.928 025	1.32	9.797 194	4.67	0.202 806	55
6	.725 420	3.37	.927 946	1.32	.797 474	4.68	.202 526	54
7	.725 622	3.35	.927 867	1.33	.797 755	4.68	.202 245	53
8	.725 823	3.35	.927 787	1.32	.798 036	4.67	.201 964	52
9	.726 024	3.35	.927 708	1.32	.798 316	4.67	.201 684	51
10	9.726 225	3.35	9.927 629	1.33	9.798 596	4.68	0.201 404	50
11	.726 426	3.33	.927 549	1.32	.798 877	4.67	.201 123	49
12	.726 626	3.35	.927 470	1.33	.799 157	4.67	.200 843	48
13	.726 827	3.33	.927 390	1.33	.799 437	4.67	.200 563	47
14	.727 027	3.35	.927 310	1.32	.799 717	4.67	.200 283	46
15	9.727 228	3.33	9.927 231	1.33	9.799 997	4.67	0.200 003	45
16	.727 428	3.33	.927 151	1.33	.800 277	4.67	.199 723	44
17	.727 628	3.33	.927 071	1.33	.800 557	4.65	.199 443	43
18	.727 828	3.32	.926 991	1.33	.800 836	4.67	.199 164	42
19	.728 027	3.33	.926 911	1.33	.801 116	4.67	.198 884	41
20	9.728 227	3.33	9.926 831	1.33	9.801 396	4.65	0.198 604	40
21	.728 427	3.32	.926 751	1.33	.801 675	4.67	.198 325	39
22	.728 626	3.32	.926 671	1.33	.801 955	4.65	.198 045	38
23	.728 825	3.32	.926 591	1.33	.802 234	4.65	.197 766	37
24	.729 024	3.32	.926 511	1.33	.802 513	4.65	.197 487	36
25	9.729 223	3.32	9.926 431	1.33	9.802 792	4.67	0.197 208	35
26	.729 422	3.32	.926 351	1.35	.803 072	4.65	.196 928	34
27	.729 621	3.32	.926 270	1.33	.803 351	4.65	.196 649	33
28	.729 820	3.30	.926 190	1.33	.803 630	4.65	.196 370	32
29	.730 018	3.32	.926 110	1.35	.803 909	4.63	.196 091	31
30	9.730 217	3.30	9.926 029	1.33	9.804 187	4.65	0.195 813	30
31	.730 415	3.30	.925 949	1.35	.804 466	4.65	.195 534	29
32	.730 613	3.30	.925 868	1.33	.804 745	4.63	.195 255	28
33	.730 811	3.30	.925 788	1.35	.805 023	4.65	.194 977	27
34	.731 009	3.28	.925 707	1.35	.805 302	4.63	.194 698	26
35	9.731 206	3.30	9.925 626	1.35	9.805 580	4.65	0.194 420	25
36	.731 404	3.30	.925 545	1.33	.805 859	4.63	.194 141	24
37	.731 602	3.28	.925 465	1.35	.806 137	4.63	.193 863	23
38	.731 799	3.28	.925 384	1.35	.806 415	4.63	.193 585	22
39	.731 996	3.28	.925 303	1.35	.806 693	4.63	.193 307	21
40	9.732 193	3.28	9.925 222	1.35	9.806 971	4.63	0.193 029	20
41	.732 390	3.28	.925 141	1.35	.807 249	4.63	.192 751	19
42	.732 587	3.28	.925 060	1.35	.807 527	4.63	.192 473	18
43	.732 784	3.27	.924 979	1.37	.807 805	4.63	.192 195	17
44	.732 980	3.28	.924 897	1.35	.808 083	4.63	.191 917	16
45	9.733 177	3.27	9.924 816	1.35	9.808 361	4.62	0.191 639	15
46	.733 373	3.27	.924 735	1.35	.808 638	4.63	.191 362	14
47	.733 569	3.27	.924 654	1.37	.808 916	4.62	.191 084	13
48	.733 765	3.27	.924 572	1.35	.809 193	4.63	.190 807	12
49	.733 961	3.27	.924 491	1.37	.809 471	4.62	.190 529	11
50	9.734 157	3.27	9.924 409	1.35	9.809 748	4.62	0.190 252	10
51	.734 353	3.27	.924 328	1.37	.810 025	4.62	.189 975	9
52	.734 549	3.25	.924 246	1.37	.810 302	4.63	.189 698	8
53	.734 744	3.25	.924 164	1.35	.810 580	4.62	.189 420	7
54	.734 939	3.27	.924 083	1.37	.810 857	4.62	.189 143	6
55	9.735 135	3.25	9.924 001	1.37	9.811 134	4.60	0.188 866	5
56	.735 330	3.25	.923 919	1.37	.811 410	4.62	.188 590	4
57	.735 525	3.23	.923 837	1.37	.811 687	4.62	.188 313	3
58	.735 719	3.25	.923 755	1.37	.811 964	4.62	.188 036	2
59	.735 914	3.25	.923 673	1.37	.812 241	4.60	.187 759	1
60	9.736 109		9.923 591		9.812 517		0.187 483	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

57°

33°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.736 109	3.23	9.923 591	1.37	9.812 517	4.62	0.187 483	60
1	.736 303	3.25	.923 509	1.37	.812 794	4.60	.187 206	59
2	.736 498	3.23	.923 427	1.37	.813 070	4.62	.186 930	58
3	.736 692	3.23	.923 345	1.37	.813 347	4.60	.186 653	57
4	.736 886	3.23	.923 263	1.37	.813 623	4.60	.186 377	56
5	9.737 080	3.23	9.923 181	1.38	9.813 899	4.62	0.186 101	55
6	.737 274	3.22	.923 098	1.37	.814 176	4.60	.185 824	54
7	.737 467	3.23	.923 016	1.38	.814 452	4.60	.185 548	53
8	.737 661	3.23	.922 933	1.37	.814 728	4.60	.185 272	52
9	.737 855	3.22	.922 851	1.38	.815 004	4.60	.184 996	51
10	9.738 048	3.22	9.922 768	1.37	9.815 280	4.58	0.184 720	50
11	.738 241	3.22	.922 686	1.38	.815 555	4.60	.184 445	49
12	.738 434	3.22	.922 603	1.38	.815 831	4.60	.184 169	48
13	.738 627	3.22	.922 520	1.37	.816 107	4.58	.183 893	47
14	.738 820	3.22	.922 438	1.38	.816 382	4.60	.183 618	46
15	9.739 013	3.22	9.922 355	1.38	9.816 658	4.58	0.183 342	45
16	.739 206	3.20	.922 272	1.38	.816 933	4.60	.183 067	44
17	.739 398	3.20	.922 189	1.38	.817 209	4.58	.182 791	43
18	.739 590	3.22	.922 106	1.38	.817 484	4.58	.182 516	42
19	.739 783	3.20	.922 023	1.38	.817 759	4.60	.182 241	41
20	9.739 975	3.20	9.921 940	1.38	9.818 035	4.58	0.181 965	40
21	.740 167	3.20	.921 857	1.38	.818 310	4.58	.181 690	39
22	.740 359	3.18	.921 774	1.38	.818 585	4.58	.181 415	38
23	.740 550	3.20	.921 691	1.40	.818 860	4.58	.181 140	37
24	.740 742	3.20	.921 607	1.38	.819 135	4.58	.180 865	36
25	9.740 934	3.18	9.921 524	1.38	9.819 410	4.57	0.180 590	35
26	.741 125	3.18	.921 441	1.40	.819 684	4.58	.180 316	34
27	.741 316	3.20	.921 357	1.38	.819 959	4.58	.180 041	33
28	.741 508	3.18	.921 274	1.40	.820 234	4.57	.179 766	32
29	.741 699	3.17	.921 190	1.38	.820 508	4.58	.179 492	31
30	9.741 889	3.18	9.921 107	1.40	9.820 783	4.57	0.179 217	30
31	.742 080	3.18	.921 023	1.40	.821 057	4.58	.178 943	29
32	.742 271	3.18	.920 939	1.38	.821 332	4.57	.178 668	28
33	.742 462	3.17	.920 856	1.40	.821 606	4.57	.178 394	27
34	.742 652	3.17	.920 772	1.40	.821 880	4.57	.178 120	26
35	9.742 842	3.18	9.920 688	1.40	9.822 154	4.58	0.177 846	25
36	.743 033	3.17	.920 604	1.40	.822 429	4.57	.177 571	24
37	.743 223	3.17	.920 520	1.40	.822 703	4.57	.177 297	23
38	.743 413	3.15	.920 436	1.40	.822 977	4.57	.177 023	22
39	.743 602	3.17	.920 352	1.40	.823 251	4.55	.176 749	21
40	9.743 792	3.17	9.920 268	1.40	9.823 524	4.57	0.176 476	20
41	.743 982	3.15	.920 184	1.42	.823 798	4.57	.176 202	19
42	.744 171	3.17	.920 099	1.40	.824 072	4.55	.175 928	18
43	.744 361	3.15	.920 015	1.40	.824 345	4.57	.175 655	17
44	.744 550	3.15	.919 931	1.42	.824 619	4.57	.175 381	16
45	9.744 739	3.15	9.919 846	1.40	9.824 893	4.55	0.175 107	15
46	.744 928	3.15	.919 762	1.42	.825 166	4.55	.174 834	14
47	.745 117	3.15	.919 677	1.40	.825 439	4.57	.174 561	13
48	.745 306	3.13	.919 593	1.42	.825 713	4.55	.174 287	12
49	.745 494	3.15	.919 508	1.40	.825 986	4.55	.174 014	11
50	9.745 683	3.13	9.919 424	1.42	9.826 259	4.55	0.173 741	10
51	.745 871	3.15	.919 339	1.42	.826 532	4.55	.173 468	9
52	.746 060	3.13	.919 254	1.42	.826 805	4.55	.173 195	8
53	.746 248	3.13	.919 169	1.40	.827 078	4.55	.172 922	7
54	.746 436	3.13	.919 085	1.42	.827 351	4.55	.172 649	6
55	9.746 624	3.13	9.919 000	1.42	9.827 624	4.55	0.172 376	5
56	.746 812	3.12	.918 915	1.42	.827 897	4.55	.172 103	4
57	.746 999	3.13	.918 830	1.42	.828 170	4.53	.171 830	3
58	.747 187	3.12	.918 745	1.43	.828 442	4.55	.171 558	2
59	.747 374	3.13	.918 659	1.42	.828 715	4.53	.171 285	1
60	9.747 562		9.918 574		9.828 987		0.171 013	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

56°

34°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.747 562	3.12	9.918 574	1.42	9.828 987	4.55	0.171 013	60
1	.747 749	3.12	.918 489	1.42	.829 260	4.53	.170 740	59
2	.747 936	3.12	.918 404	1.43	.829 532	4.55	.170 468	58
3	.748 123	3.12	.918 318	1.42	.829 805	4.53	.170 195	57
4	.748 310	3.12	.918 233	1.43	.830 077	4.53	.169 923	56
5	9.748 497	3.10	9.918 147	1.42	9.830 349	4.53	0.169 651	55
6	.748 683	3.12	.918 062	1.43	.830 621	4.53	.169 379	54
7	.748 870	3.10	.917 976	1.42	.830 893	4.53	.169 107	53
8	.749 056	3.12	.917 891	1.43	.831 165	4.53	.168 835	52
9	.749 243	3.10	.917 805	1.43	.831 437	4.53	.168 563	51
10	9.749 429	3.10	9.917 719	1.42	9.831 709	4.53	0.168 291	50
11	.749 615	3.10	.917 634	1.43	.831 981	4.53	.168 019	49
12	.749 801	3.10	.917 548	1.43	.832 253	4.53	.167 747	48
13	.749 987	3.08	.917 462	1.43	.832 525	4.52	.167 475	47
14	.750 172	3.10	.917 376	1.43	.832 796	4.53	.167 204	46
15	9.750 358	3.08	9.917 290	1.43	9.833 068	4.52	0.166 932	45
16	.750 543	3.10	.917 204	1.43	.833 339	4.53	.166 661	44
17	.750 729	3.08	.917 118	1.43	.833 611	4.52	.166 389	43
18	.750 914	3.08	.917 032	1.43	.833 882	4.53	.166 118	42
19	.751 099	3.08	.916 946	1.45	.834 154	4.52	.165 846	41
20	9.751 284	3.08	9.916 859	1.43	9.834 425	4.52	0.165 575	40
21	.751 469	3.08	.916 773	1.43	.834 696	4.52	.165 304	39
22	.751 654	3.08	.916 687	1.45	.834 967	4.52	.165 033	38
23	.751 839	3.07	.916 600	1.43	.835 238	4.52	.164 762	37
24	.752 023	3.08	.916 514	1.45	.835 509	4.52	.164 491	36
25	9.752 208	3.07	9.916 427	1.43	9.835 780	4.52	0.164 220	35
26	.752 392	3.07	.916 341	1.45	.836 051	4.52	.163 949	34
27	.752 576	3.07	.916 254	1.45	.836 322	4.52	.163 678	33
28	.752 760	3.07	.916 167	1.43	.836 593	4.52	.163 407	32
29	.752 944	3.07	.916 081	1.45	.836 864	4.50	.163 136	31
30	9.753 128	3.07	9.915 994	1.45	9.837 134	4.52	0.162 866	30
31	.753 312	3.05	.915 907	1.45	.837 405	4.50	.162 595	29
32	.753 495	3.07	.915 820	1.45	.837 675	4.52	.162 325	28
33	.753 679	3.05	.915 733	1.45	.837 946	4.50	.162 054	27
34	.753 862	3.07	.915 646	1.45	.838 216	4.52	.161 784	26
35	9.754 046	3.05	9.915 559	1.45	9.838 487	4.50	0.161 513	25
36	.754 229	3.05	.915 472	1.45	.838 757	4.50	.161 243	24
37	.754 412	3.05	.915 385	1.47	.839 027	4.50	.160 973	23
38	.754 595	3.05	.915 297	1.45	.839 297	4.52	.160 703	22
39	.754 778	3.03	.915 210	1.45	.839 568	4.50	.160 432	21
40	9.754 960	3.05	9.915 123	1.47	9.839 838	4.50	0.160 162	20
41	.755 143	3.05	.915 035	1.45	.840 108	4.50	.159 892	19
42	.755 326	3.03	.914 948	1.47	.840 378	4.50	.159 622	18
43	.755 508	3.03	.914 860	1.45	.840 648	4.48	.159 352	17
44	.755 690	3.03	.914 773	1.47	.840 917	4.50	.159 083	16
45	9.755 872	3.03	9.914 685	1.45	9.841 187	4.50	0.158 813	15
46	.756 054	3.03	.914 598	1.47	.841 457	4.50	.158 543	14
47	.756 236	3.03	.914 510	1.47	.841 727	4.48	.158 273	13
48	.756 418	3.03	.914 422	1.47	.841 996	4.50	.158 004	12
49	.756 600	3.03	.914 334	1.47	.842 266	4.48	.157 734	11
50	9.756 782	3.02	9.914 246	1.47	9.842 535	4.50	0.157 465	10
51	.756 963	3.02	.914 158	1.47	.842 805	4.48	.157 195	9
52	.757 144	3.03	.914 070	1.47	.843 074	4.48	.156 926	8
53	.757 326	3.02	.913 982	1.47	.843 343	4.48	.156 657	7
54	.757 507	3.02	.913 894	1.47	.843 612	4.50	.156 388	6
55	9.757 688	3.02	9.913 806	1.47	9.843 882	4.48	0.156 118	5
56	.757 869	3.02	.913 718	1.47	.844 151	4.48	.155 849	4
57	.758 050	3.00	.913 630	1.48	.844 420	4.48	.155 580	3
58	.758 230	3.02	.913 541	1.47	.844 689	4.48	.155 311	2
59	.758 411	3.00	.913 453	1.47	.844 958	4.48	.155 042	1
60	9.758 591		9.913 365		9.845 227		0.154 773	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

55°

35°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.758 591	3.02	9.913 365	1.48	9.845 227	4.48	0.154 773	60
1	.758 772	3.00	.913 276	1.48	.845 496	4.47	.154 504	59
2	.758 952	3.00	.913 187	1.47	.845 764	4.48	.154 236	58
3	.759 132	3.00	.913 099	1.48	.846 033	4.48	.153 967	57
4	.759 312	3.00	.913 010	1.47	.846 302	4.47	.153 698	56
5	9.759 492	3.00	9.912 922	1.48	9.846 570	4.48	0.153 430	55
6	.759 672	3.00	.912 833	1.48	.846 839	4.48	.153 161	54
7	.759 852	2.98	.912 744	1.48	.847 108	4.47	.152 892	53
8	.760 031	3.00	.912 655	1.48	.847 376	4.47	.152 624	52
9	.760 211	2.98	.912 566	1.48	.847 644	4.48	.152 356	51
10	9.760 390	2.98	9.912 477	1.48	9.847 913	4.47	0.152 087	50
11	.760 569	2.98	.912 388	1.48	.848 181	4.47	.151 819	49
12	.760 748	2.98	.912 299	1.48	.848 449	4.47	.151 551	48
13	.760 927	2.98	.912 210	1.48	.848 717	4.48	.151 283	47
14	.761 106	2.98	.912 121	1.50	.848 986	4.47	.151 014	46
15	9.761 285	2.98	9.912 031	1.48	9.849 254	4.47	0.150 746	45
16	.761 464	2.97	.911 942	1.48	.849 522	4.47	.150 478	44
17	.761 642	2.98	.911 853	1.50	.849 790	4.45	.150 210	43
18	.761 821	2.97	.911 763	1.48	.850 057	4.47	.149 943	42
19	.761 999	2.97	.911 674	1.50	.850 325	4.47	.149 675	41
20	9.762 177	2.98	9.911 584	1.48	9.850 593	4.47	0.149 407	40
21	.762 356	2.97	.911 495	1.50	.850 861	4.47	.149 139	39
22	.762 534	2.97	.911 405	1.50	.851 129	4.45	.148 871	38
23	.762 712	2.95	.911 315	1.48	.851 396	4.47	.148 604	37
24	.762 889	2.97	.911 226	1.50	.851 664	4.45	.148 336	36
25	9.763 067	2.97	9.911 136	1.50	9.851 931	4.47	0.148 069	35
26	.763 245	2.95	.911 046	1.50	.852 199	4.45	.147 801	34
27	.763 422	2.97	.910 956	1.50	.852 466	4.45	.147 534	33
28	.763 600	2.95	.910 866	1.50	.852 733	4.47	.147 267	32
29	.763 777	2.95	.910 776	1.50	.853 001	4.45	.146 999	31
30	9.763 954	2.95	9.910 686	1.50	9.853 268	4.45	0.146 732	30
31	.764 131	2.95	.910 596	1.50	.853 535	4.45	.146 465	29
32	.764 308	2.95	.910 506	1.52	.853 802	4.45	.146 198	28
33	.764 485	2.95	.910 415	1.50	.854 069	4.45	.145 931	27
34	.764 662	2.93	.910 325	1.50	.854 336	4.45	.145 664	26
35	9.764 838	2.95	9.910 235	1.52	9.854 603	4.45	0.145 397	25
36	.765 015	2.93	.910 144	1.50	.854 870	4.45	.145 130	24
37	.765 191	2.93	.910 054	1.52	.855 137	4.45	.144 863	23
38	.765 367	2.95	.909 963	1.50	.855 404	4.45	.144 596	22
39	.765 544	2.93	.909 873	1.52	.855 671	4.45	.144 329	21
40	9.765 720	2.93	9.909 782	1.52	9.855 938	4.43	0.144 062	20
41	.765 896	2.93	.909 691	1.50	.856 204	4.45	.143 796	19
42	.766 072	2.92	.909 601	1.52	.856 471	4.43	.143 529	18
43	.766 247	2.93	.909 510	1.52	.856 737	4.45	.143 263	17
44	.766 423	2.92	.909 419	1.52	.857 004	4.43	.142 996	16
45	9.766 598	2.93	9.909 328	1.52	9.857 270	4.45	0.142 730	15
46	.766 774	2.92	.909 237	1.52	.857 537	4.43	.142 463	14
47	.766 949	2.92	.909 146	1.52	.857 803	4.43	.142 197	13
48	.767 124	2.93	.909 055	1.52	.858 069	4.45	.141 931	12
49	.767 300	2.92	.908 964	1.52	.858 336	4.43	.141 664	11
50	9.767 475	2.90	9.908 873	1.53	9.858 602	4.43	0.141 398	10
51	.767 649	2.92	.908 781	1.52	.858 868	4.43	.141 132	9
52	.767 824	2.92	.908 690	1.52	.859 134	4.43	.140 866	8
53	.767 999	2.90	.908 599	1.53	.859 400	4.43	.140 600	7
54	.768 173	2.92	.908 507	1.52	.859 666	4.43	.140 334	6
55	9.768 348	2.90	9.908 416	1.53	9.859 932	4.43	0.140 068	5
56	.768 522	2.92	.908 324	1.52	.860 198	4.43	.139 802	4
57	.768 697	2.90	.908 233	1.53	.860 464	4.43	.139 536	3
58	.768 871	2.90	.908 141	1.53	.860 730	4.42	.139 270	2
59	.769 045	2.90	.908 049	1.52	.860 995	4.43	.139 005	1
60	9.769 219		9.907 958		9.861 261		0.138 739	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

54°

36°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.769 219	2.90	9.907 958	1.53	9.861 261	4.43	0.138 739	60
1	.769 393	2.88	.907 866	1.53	.861 527	4.42	.138 473	59
2	.769 566	2.90	.907 774	1.53	.861 792	4.43	.138 208	58
3	.769 740	2.88	.907 682	1.53	.862 058	4.42	.137 942	57
4	.769 913	2.90	.907 590	1.53	.862 323	4.43	.137 677	56
5	9.770 087	2.88	9.907 498	1.53	9.862 589	4.42	0.137 411	55
6	.770 260	2.88	.907 406	1.53	.862 854	4.42	.137 146	54
7	.770 433	2.88	.907 314	1.53	.863 119	4.43	.136 881	53
8	.770 606	2.88	.907 222	1.55	.863 385	4.42	.136 615	52
9	.770 779	2.88	.907 129	1.53	.863 650	4.42	.136 350	51
10	9.770 952	2.88	9.907 037	1.53	9.863 915	4.42	0.136 085	50
11	.771 125	2.88	.906 945	1.55	.864 180	4.42	.135 820	49
12	.771 298	2.87	.906 852	1.53	.864 445	4.42	.135 555	48
13	.771 470	2.88	.906 760	1.55	.864 710	4.42	.135 290	47
14	.771 643	2.87	.906 667	1.53	.864 975	4.42	.135 025	46
15	9.771 815	2.87	9.906 575	1.55	9.865 240	4.42	0.134 760	45
16	.771 987	2.87	.906 482	1.55	.865 505	4.42	.134 495	44
17	.772 159	2.87	.906 389	1.55	.865 770	4.42	.134 230	43
18	.772 331	2.87	.906 296	1.53	.866 035	4.42	.133 965	42
19	.772 503	2.87	.906 204	1.55	.866 300	4.40	.133 700	41
20	9.772 675	2.87	9.906 111	1.55	9.866 564	4.42	0.133 436	40
21	.772 847	2.85	.906 018	1.55	.866 829	4.42	.133 171	39
22	.773 018	2.87	.905 925	1.55	.867 094	4.40	.132 906	38
23	.773 190	2.85	.905 832	1.55	.867 358	4.42	.132 642	37
24	.773 361	2.87	.905 739	1.57	.867 623	4.40	.132 377	36
25	9.773 533	2.85	9.905 645	1.55	9.867 887	4.42	0.132 113	35
26	.773 704	2.85	.905 552	1.55	.868 152	4.40	.131 848	34
27	.773 875	2.85	.905 459	1.55	.868 416	4.40	.131 584	33
28	.774 046	2.85	.905 366	1.57	.868 680	4.42	.131 320	32
29	.774 217	2.85	.905 272	1.55	.868 945	4.40	.131 055	31
30	9.774 388	2.83	9.905 179	1.57	9.869 209	4.40	0.130 791	30
31	.774 558	2.85	.905 085	1.55	.869 473	4.40	.130 527	29
32	.774 729	2.83	.904 992	1.57	.869 737	4.40	.130 263	28
33	.774 899	2.85	.904 898	1.57	.870 001	4.40	.129 999	27
34	.775 070	2.83	.904 804	1.55	.870 265	4.40	.129 735	26
35	9.775 240	2.83	9.904 711	1.57	9.870 529	4.40	0.129 471	25
36	.775 410	2.83	.904 617	1.57	.870 793	4.40	.129 207	24
37	.775 580	2.83	.904 523	1.57	.871 057	4.40	.128 943	23
38	.775 750	2.83	.904 429	1.57	.871 321	4.40	.128 679	22
39	.775 920	2.83	.904 335	1.57	.871 585	4.40	.128 415	21
40	9.776 090	2.82	9.904 241	1.57	9.871 849	4.38	0.128 151	20
41	.776 259	2.83	.904 147	1.57	.872 112	4.40	.127 888	19
42	.776 429	2.82	.904 053	1.57	.872 376	4.40	.127 624	18
43	.776 598	2.83	.903 959	1.58	.872 640	4.38	.127 360	17
44	.776 768	2.82	.903 864	1.57	.872 903	4.40	.127 097	16
45	9.776 937	2.82	9.903 770	1.57	9.873 167	4.38	0.126 833	15
46	.777 106	2.82	.903 676	1.58	.873 430	4.40	.126 570	14
47	.777 275	2.82	.903 581	1.57	.873 694	4.38	.126 306	13
48	.777 444	2.82	.903 487	1.58	.873 957	4.38	.126 043	12
49	.777 613	2.80	.903 392	1.57	.874 220	4.40	.125 780	11
50	9.777 781	2.82	9.903 298	1.58	9.874 484	4.38	0.125 516	10
51	.777 950	2.82	.903 203	1.58	.874 747	4.38	.125 253	9
52	.778 119	2.80	.903 108	1.57	.875 010	4.38	.124 990	8
53	.778 287	2.80	.903 014	1.58	.875 273	4.40	.124 727	7
54	.778 455	2.82	.902 919	1.58	.875 537	4.38	.124 463	6
55	9.778 624	2.80	9.902 824	1.58	9.875 800	4.38	0.124 200	5
56	.778 792	2.80	.902 729	1.58	.876 063	4.38	.123 937	4
57	.778 960	2.80	.902 634	1.58	.876 326	4.38	.123 674	3
58	.779 128	2.78	.902 539	1.58	.876 589	4.38	.123 411	2
59	.779 295	2.80	.902 444	1.58	.876 852	4.37	.123 148	1
60	9.779 463		9.902 349		9.877 114		0.122 886	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

53°

37°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.779 463	2.80	9.902 349	1.60	9.877 114	4.38	0.122 886	60
1	.779 631	2.78	.902 253	1.58	.877 377	4.38	.122 623	59
2	.779 798	2.80	.902 158	1.58	.877 640	4.38	.122 360	58
3	.779 966	2.78	.902 063	1.60	.877 903	4.37	.122 097	57
4	.780 133	2.78	.901 967	1.58	.878 165	4.38	.121 835	56
5	9.780 300	2.78	9.901 872	1.60	9.878 428	4.38	0.121 572	55
6	.780 467	2.78	.901 776	1.58	.878 691	4.37	.121 309	54
7	.780 634	2.78	.901 681	1.60	.878 953	4.38	.121 047	53
8	.780 801	2.78	.901 585	1.58	.879 216	4.37	.120 784	52
9	.780 968	2.77	.901 490	1.60	.879 478	4.38	.120 522	51
10	9.781 134	2.78	9.901 394	1.60	9.879 741	4.37	0.120 259	50
11	.781 301	2.78	.901 298	1.60	.880 003	4.37	.119 997	49
12	.781 468	2.77	.901 202	1.60	.880 265	4.38	.119 735	48
13	.781 634	2.77	.901 106	1.60	.880 528	4.37	.119 472	47
14	.781 800	2.77	.901 010	1.60	.880 790	4.37	.119 210	46
15	9.781 966	2.77	9.900 914	1.60	9.881 052	4.37	0.118 948	45
16	.782 132	2.77	.900 818	1.60	.881 314	4.38	.118 686	44
17	.782 298	2.77	.900 722	1.60	.881 577	4.37	.118 423	43
18	.782 464	2.77	.900 626	1.62	.881 839	4.37	.118 161	42
19	.782 630	2.77	.900 529	1.60	.882 101	4.37	.117 899	41
20	9.782 796	2.75	9.900 433	1.60	9.882 363	4.37	0.117 637	40
21	.782 961	2.77	.900 337	1.62	.882 625	4.37	.117 375	39
22	.783 127	2.75	.900 240	1.60	.882 887	4.35	.117 113	38
23	.783 292	2.77	.900 144	1.62	.883 148	4.37	.116 852	37
24	.783 458	2.75	.900 047	1.60	.883 410	4.37	.116 590	36
25	9.783 623	2.75	9.899 951	1.62	9.883 672	4.37	0.116 328	35
26	.783 788	2.75	.899 854	1.62	.883 934	4.37	.116 066	34
27	.783 953	2.75	.899 757	1.62	.884 196	4.35	.115 804	33
28	.784 118	2.73	.899 660	1.60	.884 457	4.37	.115 543	32
29	.784 282	2.75	.899 564	1.62	.884 719	4.35	.115 281	31
30	9.784 447	2.75	9.899 467	1.62	9.884 980	4.37	0.115 020	30
31	.784 612	2.73	.899 370	1.62	.885 242	4.37	.114 758	29
32	.784 776	2.75	.899 273	1.62	.885 504	4.35	.114 496	28
33	.784 941	2.73	.899 176	1.63	.885 765	4.35	.114 235	27
34	.785 105	2.73	.899 078	1.62	.886 026	4.37	.113 974	26
35	9.785 269	2.73	9.898 981	1.62	9.886 288	4.35	0.113 712	25
36	.785 433	2.73	.898 884	1.62	.886 549	4.37	.113 451	24
37	.785 597	2.73	.898 787	1.63	.886 811	4.35	.113 189	23
38	.785 761	2.73	.898 689	1.62	.887 072	4.35	.112 928	22
39	.785 925	2.73	.898 592	1.63	.887 333	4.35	.112 667	21
40	9.786 089	2.72	9.898 494	1.62	9.887 594	4.35	0.112 406	20
41	.786 252	2.73	.898 397	1.63	.887 855	4.35	.112 145	19
42	.786 416	2.72	.898 299	1.62	.888 116	4.37	.111 884	18
43	.786 579	2.72	.898 202	1.63	.888 378	4.35	.111 622	17
44	.786 742	2.73	.898 104	1.63	.888 639	4.35	.111 361	16
45	9.786 906	2.72	9.898 006	1.63	9.888 900	4.35	0.111 100	15
46	.787 069	2.72	.897 908	1.63	.889 161	4.33	.110 839	14
47	.787 232	2.72	.897 810	1.63	.889 421	4.35	.110 579	13
48	.787 395	2.70	.897 712	1.63	.889 682	4.35	.110 318	12
49	.787 557	2.72	.897 614	1.63	.889 943	4.35	.110 057	11
50	9.787 720	2.72	9.897 516	1.63	9.890 204	4.35	0.109 796	10
51	.787 883	2.70	.897 418	1.63	.890 465	4.33	.109 535	9
52	.788 045	2.72	.897 320	1.63	.890 725	4.35	.109 275	8
53	.788 208	2.70	.897 222	1.65	.890 986	4.35	.109 014	7
54	.788 370	2.70	.897 123	1.63	.891 247	4.33	.108 753	6
55	9.788 532	2.70	9.897 025	1.65	9.891 507	4.35	0.108 493	5
56	.788 694	2.70	.896 926	1.63	.891 768	4.33	.108 232	4
57	.788 856	2.70	.896 828	1.65	.892 028	4.35	.107 972	3
58	.789 018	2.70	.896 729	1.63	.892 289	4.33	.107 711	2
59	.789 180	2.70	.896 631	1.65	.892 549	4.35	.107 451	1
60	9.789 342		9.896 532		9.892 810		0.107 190	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

52°

38°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.789 342	2.70	9.896 532	1.65	9.892 810	4.33	0.107 190	60
1	.789 504	2.68	.896 433	1.63	.893 070	4.35	.106 930	59
2	.789 665	2.70	.896 335	1.65	.893 331	4.33	.106 669	58
3	.789 827	2.68	.896 236	1.65	.893 591	4.33	.106 409	57
4	.789 988	2.68	.896 137	1.65	.893 851	4.33	.106 149	56
5	9.790 149	2.68	9.896 038	1.65	9.894 111	4.35	0.105 889	55
6	.790 310	2.68	.895 939	1.65	.894 372	4.33	.105 628	54
7	.790 471	2.68	.895 840	1.65	.894 632	4.33	.105 368	53
8	.790 632	2.68	.895 741	1.67	.894 892	4.33	.105 108	52
9	.790 793	2.68	.895 641	1.65	.895 152	4.33	.104 848	51
10	9.790 954	2.68	9.895 542	1.65	9.895 412	4.33	0.104 588	50
11	.791 115	2.67	.895 443	1.67	.895 672	4.33	.104 328	49
12	.791 275	2.68	.895 343	1.65	.895 932	4.33	.104 068	48
13	.791 436	2.67	.895 244	1.65	.896 192	4.33	.103 808	47
14	.791 596	2.68	.895 145	1.67	.896 452	4.33	.103 548	46
15	9.791 757	2.67	9.895 045	1.67	9.896 712	4.32	0.103 288	45
16	.791 917	2.67	.894 945	1.65	.896 971	4.33	.103 029	44
17	.792 077	2.67	.894 846	1.67	.897 231	4.33	.102 769	43
18	.792 237	2.67	.894 746	1.67	.897 491	4.33	.102 509	42
19	.792 397	2.67	.894 646	1.67	.897 751	4.32	.102 249	41
20	9.792 557	2.65	9.894 546	1.67	9.898 010	4.33	0.101 990	40
21	.792 716	2.67	.894 446	1.67	.898 270	4.33	.101 730	39
22	.792 876	2.65	.894 346	1.67	.898 530	4.32	.101 470	38
23	.793 035	2.67	.894 246	1.67	.898 789	4.33	.101 211	37
24	.793 195	2.65	.894 146	1.67	.899 049	4.32	.100 951	36
25	9.793 354	2.67	9.894 046	1.67	9.899 308	4.33	0.100 692	35
26	.793 514	2.65	.893 946	1.67	.899 568	4.32	.100 432	34
27	.793 673	2.65	.893 846	1.68	.899 827	4.33	.100 173	33
28	.793 832	2.65	.893 745	1.67	.900 087	4.32	.099 913	32
29	.793 991	2.65	.893 645	1.68	.900 346	4.32	.099 654	31
30	9.794 150	2.63	9.893 544	1.67	9.900 605	4.32	0.099 395	30
31	.794 308	2.65	.893 444	1.68	.900 864	4.33	.099 136	29
32	.794 467	2.65	.893 343	1.67	.901 124	4.32	.098 876	28
33	.794 626	2.63	.893 243	1.68	.901 383	4.32	.098 617	27
34	.794 784	2.63	.893 142	1.68	.901 642	4.32	.098 358	26
35	9.794 942	2.65	9.893 041	1.68	9.901 901	4.32	0.098 099	25
36	.795 101	2.63	.892 940	1.68	.902 160	4.33	.097 840	24
37	.795 259	2.63	.892 839	1.67	.902 420	4.32	.097 580	23
38	.795 417	2.63	.892 739	1.68	.902 679	4.32	.097 321	22
39	.795 575	2.63	.892 638	1.70	.902 938	4.32	.097 062	21
40	9.795 733	2.63	9.892 536	1.68	9.903 197	4.32	0.096 803	20
41	.795 891	2.63	.892 435	1.68	.903 456	4.30	.096 544	19
42	.796 049	2.62	.892 334	1.68	.903 714	4.32	.096 286	18
43	.796 206	2.63	.892 233	1.68	.903 973	4.32	.096 027	17
44	.796 364	2.62	.892 132	1.70	.904 232	4.32	.095 768	16
45	9.796 521	2.63	9.892 030	1.68	9.904 491	4.32	0.095 509	15
46	.796 679	2.62	.891 929	1.70	.904 750	4.30	.095 250	14
47	.796 836	2.62	.891 827	1.68	.905 008	4.32	.094 992	13
48	.796 993	2.62	.891 726	1.70	.905 267	4.32	.094 733	12
49	.797 150	2.62	.891 624	1.68	.905 526	4.32	.094 474	11
50	9.797 307	2.62	9.891 523	1.70	9.905 785	4.30	0.094 215	10
51	.797 464	2.62	.891 421	1.70	.906 043	4.32	.093 957	9
52	.797 621	2.60	.891 319	1.70	.906 302	4.30	.093 698	8
53	.797 777	2.62	.891 217	1.70	.906 560	4.32	.093 440	7
54	.797 934	2.62	.891 115	1.70	.906 819	4.30	.093 181	6
55	9.798 091	2.60	9.891 013	1.70	9.907 077	4.32	0.092 923	5
56	.798 247	2.60	.890 911	1.70	.907 336	4.30	.092 664	4
57	.798 403	2.62	.890 809	1.70	.907 594	4.32	.092 406	3
58	.798 560	2.60	.890 707	1.70	.907 853	4.30	.092 147	2
59	.798 716	2.60	.890 605	1.70	.908 111	4.30	.091 889	1
60	9.798 872		9.890 503		9.908 369		0.091 631	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

51°

39°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.798 872	2.60	9.890 503	1.72	9.908 369	4.32	0.091 631	60
1	.799 028	2.60	.890 400	1.70	.908 628	4.30	.091 372	59
2	.799 184	2.58	.890 298	1.72	.908 886	4.30	.091 114	58
3	.799 339	2.60	.890 195	1.70	.909 144	4.30	.090 856	57
4	.799 495	2.60	.890 093	1.72	.909 402	4.30	.090 598	56
5	9.799 651	2.58	9.889 990	1.70	9.909 660	4.30	0.090 340	55
6	.799 806	2.60	.889 888	1.72	.909 918	4.32	.090 082	54
7	.799 962	2.58	.889 785	1.72	.910 177	4.30	.089 823	53
8	.800 117	2.58	.889 682	1.72	.910 435	4.30	.089 565	52
9	.800 272	2.58	.889 579	1.70	.910 693	4.30	.089 307	51
10	9.800 427	2.58	9.889 477	1.72	9.910 951	4.30	0.089 049	50
11	.800 582	2.58	.889 374	1.72	.911 209	4.30	.088 791	49
12	.800 737	2.58	.889 271	1.72	.911 467	4.30	.088 533	48
13	.800 892	2.58	.889 168	1.73	.911 725	4.28	.088 275	47
14	.801 047	2.57	.889 064	1.72	.911 982	4.30	.088 018	46
15	9.801 201	2.58	9.888 961	1.72	9.912 240	4.30	0.087 760	45
16	.801 356	2.58	.888 858	1.72	.912 498	4.30	.087 502	44
17	.801 511	2.57	.888 755	1.73	.912 756	4.30	.087 244	43
18	.801 665	2.57	.888 651	1.72	.913 014	4.28	.086 986	42
19	.801 819	2.57	.888 548	1.73	.913 271	4.30	.086 729	41
20	9.801 973	2.58	9.888 444	1.72	9.913 529	4.30	0.086 471	40
21	.802 128	2.57	.888 341	1.73	.913 787	4.28	.086 213	39
22	.802 282	2.57	.888 237	1.72	.914 044	4.30	.085 956	38
23	.802 436	2.55	.888 134	1.73	.914 302	4.30	.085 698	37
24	.802 589	2.57	.888 030	1.73	.914 560	4.28	.085 440	36
25	9.802 743	2.57	9.887 926	1.73	9.914 817	4.30	0.085 183	35
26	.802 897	2.55	.887 822	1.73	.915 075	4.28	.084 925	34
27	.803 050	2.57	.887 718	1.73	.915 332	4.30	.084 668	33
28	.803 204	2.55	.887 614	1.73	.915 590	4.28	.084 410	32
29	.803 357	2.57	.887 510	1.73	.915 847	4.28	.084 153	31
30	9.803 511	2.55	9.887 406	1.73	9.916 104	4.30	0.083 896	30
31	.803 664	2.55	.887 302	1.73	.916 362	4.28	.083 638	29
32	.803 817	2.55	.887 198	1.75	.916 619	4.30	.083 381	28
33	.803 970	2.55	.887 093	1.73	.916 877	4.28	.083 123	27
34	.804 123	2.55	.886 989	1.73	.917 134	4.28	.082 866	26
35	9.804 276	2.53	9.886 885	1.75	9.917 391	4.28	0.082 609	25
36	.804 428	2.55	.886 780	1.73	.917 648	4.30	.082 352	24
37	.804 581	2.55	.886 676	1.75	.917 906	4.28	.082 094	23
38	.804 734	2.53	.886 571	1.75	.918 163	4.28	.081 837	22
39	.804 886	2.55	.886 466	1.73	.918 420	4.28	.081 580	21
40	9.805 039	2.53	9.886 362	1.75	9.918 677	4.28	0.081 323	20
41	.805 191	2.53	.886 257	1.75	.918 934	4.28	.081 066	19
42	.805 343	2.53	.886 152	1.75	.919 191	4.28	.080 809	18
43	.805 495	2.53	.886 047	1.75	.919 448	4.28	.080 552	17
44	.805 647	2.53	.885 942	1.75	.919 705	4.28	.080 295	16
45	9.805 799	2.53	9.885 837	1.75	9.919 962	4.28	0.080 038	15
46	.805 951	2.53	.885 732	1.75	.920 219	4.28	.079 781	14
47	.806 103	2.52	.885 627	1.75	.920 476	4.28	.079 524	13
48	.806 254	2.53	.885 522	1.77	.920 733	4.28	.079 267	12
49	.806 406	2.52	.885 416	1.75	.920 990	4.28	.079 010	11
50	9.806 557	2.53	9.885 311	1.77	9.921 247	4.27	0.078 753	10
51	.806 709	2.52	.885 205	1.75	.921 503	4.28	.078 497	9
52	.806 860	2.52	.885 100	1.77	.921 760	4.28	.078 240	8
53	.807 011	2.53	.884 994	1.75	.922 017	4.28	.077 983	7
54	.807 163	2.52	.884 889	1.77	.922 274	4.27	.077 726	6
55	9.807 314	2.52	9.884 783	1.77	9.922 530	4.28	0.077 470	5
56	.807 465	2.50	.884 677	1.75	.922 787	4.28	.077 213	4
57	.807 615	2.52	.884 572	1.77	.923 044	4.27	.076 956	3
58	.807 766	2.52	.884 466	1.77	.923 300	4.28	.076 700	2
59	.807 917	2.50	.884 360	1.77	.923 557	4.28	.076 443	1
60	9.808 067		9.884 254		9.923 814		0.076 186	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

50°

40°

M.	Sin.	D. 1″.	Cos.	D 1″.	Tan.	D. 1″.	Cot.	
0	9.808 067	2.52	9.884 254	1.77	9.923 814	4.27	0.076 186	60
1	.808 218	2.50	.884 148	1.77	.924 070	4.28	.075 930	59
2	.808 368	2.52	.884 042	1.77	.924 327	4.27	.075 673	58
3	.808 519	2.50	.883 936	1.78	.924 583	4.28	.075 417	57
4	.808 669	2.50	.883 829	1.77	.924 840	4.27	.075 160	56
5	9.808 819	2.50	9.883 723	1.77	9.925 096	4.27	0.074 904	55
6	.808 969	2.50	.883 617	1.78	.925 352	4.28	.074 648	54
7	.809 119	2.50	.883 510	1.77	.925 609	4.27	.074 391	53
8	.809 269	2.50	.883 404	1.78	.925 865	4.28	.074 135	52
9	.809 419	2.50	.883 297	1.77	.926 122	4.27	.073 878	51
10	9.809 569	2.48	9.883 191	1.78	9.926 378	4.27	0.073 622	50
11	.809 718	2.50	.883 084	1.78	.926 634	4.27	.073 366	49
12	.809 868	2.48	.882 977	1.77	.926 890	4.28	.073 110	48
13	.810 017	2.50	.882 871	1.78	.927 147	4.27	.072 853	47
14	.810 167	2.48	.882 764	1.78	.927 403	4.27	.072 597	46
15	9.810 316	2.48	9.882 657	1.78	9.927 659	4.27	0.072 341	45
16	.810 465	2.48	.882 550	1.78	.927 915	4.27	.072 085	44
17	.810 614	2.48	.882 443	1.78	.928 171	4.27	.071 829	43
18	.810 763	2.48	.882 336	1.78	.928 427	4.28	.071 573	42
19	.810 912	2.48	.882 229	1.80	.928 684	4.27	.071 316	41
20	9.811 061	2.48	9.882 121	1.78	9.928 940	4.27	0.071 060	40
21	.811 210	2.47	.882 014	1.78	.929 196	4.27	.070 804	39
22	.811 358	2.48	.881 907	1.80	.929 452	4.27	.070 548	38
23	.811 507	2.47	.881 799	1.78	.929 708	4.27	.070 292	37
24	.811 655	2.48	.881 692	1.80	.929 964	4.27	.070 036	36
25	9.811 804	2.47	9.881 584	1.78	9.930 220	4.25	0.069 780	35
26	.811 952	2.47	.881 477	1.80	.930 475	4.27	.069 525	34
27	.812 100	2.47	.881 369	1.80	.930 731	4.27	.069 269	33
28	.812 248	2.47	.881 261	1.80	.930 987	4.27	.069 013	32
29	.812 396	2.47	.881 153	1.78	.931 243	4.27	.068 757	31
30	9.812 544	2.47	9.881 046	1.80	9.931 499	4.27	0.068 501	30
31	.812 692	2.47	.880 938	1.80	.931 755	4.25	.068 245	29
32	.812 840	2.47	.880 830	1.80	.932 010	4.27	.067 990	28
33	.812 988	2.45	.880 722	1.82	.932 266	4.27	.067 734	27
34	.813 135	2.47	.880 613	1.80	.932 522	4.27	.067 478	26
35	9.813 283	2.45	9.880 505	1.80	9.932 778	4.25	0.067 222	25
36	.813 430	2.47	.880 397	1.80	.933 033	4.27	.066 967	24
37	.813 578	2.45	.880 289	1.82	.933 289	4.27	.066 711	23
38	.813 725	2.45	.880 180	1.80	.933 545	4.25	.066 455	22
39	.813 872	2.45	.880 072	1.82	.933 800	4.27	.066 200	21
40	9.814 019	2.45	9.879 963	1.80	9.934 056	4.25	0.065 944	20
41	.814 166	2.45	.879 855	1.82	.934 311	4.27	.065 689	19
42	.814 313	2.45	.879 746	1.82	.934 567	4.25	.065 433	18
43	.814 460	2.45	.879 637	1.80	.934 822	4.27	.065 178	17
44	.814 607	2.43	.879 529	1.82	.935 078	4.25	.064 922	16
45	9.814 753	2.45	9.879 420	1.82	9.935 333	4.27	0.064 667	15
46	.814 900	2.43	.879 311	1.82	.935 589	4.25	.064 411	14
47	.815 046	2.45	.879 202	1.82	.935 844	4.27	.064 156	13
48	.815 193	2.43	.879 093	1.82	.936 100	4.25	.063 900	12
49	.815 339	2.43	.878 984	1.82	.936 355	4.27	.063 645	11
50	9.815 485	2.45	9.878 875	1.82	9.936 611	4.25	0.063 389	10
51	.815 632	2.43	.878 766	1.83	.936 866	4.25	.063 134	9
52	.815 778	2.43	.878 656	1.82	.937 121	4.27	.062 879	8
53	.815 924	2.42	.878 547	1.82	.937 377	4.25	.062 623	7
54	.816 069	2.43	.878 438	1.83	.937 632	4.25	.062 368	6
55	9.816 215	2.43	9.878 328	1.82	9.937 887	4.25	0.062 113	5
56	.816 361	2.43	.878 219	1.83	.938 142	4.27	.061 858	4
57	.816 507	2.42	.878 109	1.83	.938 398	4.25	.061 602	3
58	.816 652	2.43	.877 999	1.82	.938 653	4.25	.061 347	2
59	.816 798	2.42	.877 890	1.83	.938 908	4.25	.061 092	1
60	9.816 943		9.877 780		9.939 163		0.060 837	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

49°

41°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.816 943	2.42	9.877 780	1.83	9.939 163	4.25	0.060 837	60
1	.817 088	2.42	.877 670	1.83	.939 418	4.25	.060 582	59
2	.817 233	2.43	.877 560	1.83	.939 673	4.25	.060 327	58
3	.817 379	2.42	.877 450	1.83	.939 928	4.25	.060 072	57
4	.817 524	2.40	.877 340	1.83	.940 183	4.27	.059 817	56
5	9.817 668	2.42	9.877 230	1.83	9.940 439	4.25	0.059 561	55
6	.817 813	2.42	.877 120	1.83	.940 694	4.25	.059 306	54
7	.817 958	2.42	.877 010	1.85	.940 949	4.25	.059 051	53
8	.818 103	2.40	.876 899	1.83	.941 204	4.25	.058 796	52
9	.818 247	2.42	.876 789	1.85	.941 459	4.23	.058 541	51
10	9.818 392	2.40	9.876 678	1.83	9.941 713	4.25	0.058 287	50
11	.818 536	2.42	.876 568	1.85	.941 968	4.25	.058 032	49
12	.818 681	2.40	.876 457	1.83	.942 223	4.25	.057 777	48
13	.818 825	2.40	.876 347	1.85	.942 478	4.25	.057 522	47
14	.818 969	2.40	.876 236	1.85	.942 733	4.25	.057 267	46
15	9.819 113	2.40	9.876 125	1.85	9.942 988	4.25	0.057 012	45
16	.819 257	2.40	.876 014	1.83	.943 243	4.25	.056 757	44
17	.819 401	2.40	.875 904	1.85	.943 498	4.23	.056 502	43
18	.819 545	2.40	.875 793	1.85	.943 752	4.25	.056 248	42
19	.819 689	2.38	.875 682	1.85	.944 007	4.25	.055 993	41
20	9.819 832	2.40	9.875 571	1.87	9.944 262	4.25	0.055 738	40
21	.819 976	2.40	.875 459	1.85	.944 517	4.23	.055 483	39
22	.820 120	2.38	.875 348	1.85	.944 771	4.25	.055 229	38
23	.820 263	2.38	.875 237	1.85	.945 026	4.25	.054 974	37
24	.820 406	2.40	.875 126	1.87	.945 281	4.23	.054 719	36
25	9.820 550	2.38	9.875 014	1.85	9.945 535	4.25	0.054 465	35
26	.820 693	2.38	.874 903	1.87	.945 790	4.25	.054 210	34
27	.820 836	2.38	.874 791	1.85	.946 045	4.23	.053 955	33
28	.820 979	2.38	.874 680	1.87	.946 299	4.25	.053 701	32
29	.821 122	2.38	.874 568	1.87	.946 554	4.23	.053 446	31
30	9.821 265	2.37	9.874 456	1.87	9.946 808	4.25	0.053 192	30
31	.821 407	2.38	.874 344	1.87	.947 063	4.25	.052 937	29
32	.821 550	2.38	.874 232	1.85	.947 318	4.23	.052 682	28
33	.821 693	2.37	.874 121	1.87	.947 572	4.25	.052 428	27
34	.821 835	2.37	.874 009	1.88	.947 827	4.23	.052 173	26
35	9.821 977	2.38	9.873 896	1.87	9.948 081	4.23	0.051 919	25
36	.822 120	2.37	.873 784	1.87	.948 335	4.25	.051 665	24
37	.822 262	2.37	.873 672	1.87	.948 590	4.23	.051 410	23
38	.822 404	2.37	.873 560	1.87	.948 844	4.25	.051 156	22
39	.822 546	2.37	.873 448	1.88	.949 099	4.23	.050 901	21
40	9.822 688	2.37	9.873 335	1.87	9.949 353	4.25	0.050 647	20
41	.822 830	2.37	.873 223	1.88	.949 608	4.23	.050 392	19
42	.822 972	2.37	.873 110	1.87	.949 862	4.23	.050 138	18
43	.823 114	2.35	.872 998	1.88	.950 116	4.25	.049 884	17
44	.823 255	2.37	.872 885	1.88	.950 371	4.23	.049 629	16
45	9.823 397	2.37	9.872 772	1.88	9.950 625	4.23	0.049 375	15
46	.823 539	2.35	.872 659	1.87	.950 879	4.23	.049 121	14
47	.823 680	2.35	.872 547	1.88	.951 133	4.25	.048 867	13
48	.823 821	2.37	.872 434	1.88	.951 388	4.23	.048 612	12
49	.823 963	2.35	.872 321	1.88	.951 642	4.23	.048 358	11
50	9.824 104	2.35	9.872 208	1.88	9.951 896	4.23	0.048 104	10
51	.824 245	2.35	.872 095	1.90	.952 150	4.25	.047 850	9
52	.824 386	2.35	.871 981	1.88	.952 405	4.23	.047 595	8
53	.824 527	2.35	.871 868	1.88	.952 659	4.23	.047 341	7
54	.824 668	2.33	.871 755	1.90	.952 913	4.23	.047 087	6
55	9.824 808	2.35	9.871 641	1.88	9.953 167	4.23	0.046 833	5
56	.824 949	2.35	.871 528	1.90	.953 421	4.23	.046 579	4
57	.825 090	2.33	.871 414	1.88	.953 675	4.23	.046 325	3
58	.825 230	2.35	.871 301	1.90	.953 929	4.23	.046 071	2
59	.825 371	2.33	.871 187	1.90	.954 183	4.23	.045 817	1
60	9.825 511		9.871 073		9.954 437		0.045 563	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

48°

42°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.825 511	2.33	9.871 073	1.88	9.954 437	4.23	0.045 563	60
1	.825 651	2.33	.870 960	1.90	.954 691	4.25	.045 309	59
2	.825 791	2.33	.870 846	1.90	.954 946	4.23	.045 054	58
3	.825 931	2.33	.870 732	1.90	.955 200	4.23	.044 800	57
4	.826 071	2.33	.870 618	1.90	.955 454	4.23	.044 546	56
5	9.826 211	2.33	9.870 504	1.90	9.955 708	4.22	0.044 292	55
6	.826 351	2.33	.870 390	1.90	.955 961	4.23	.044 039	54
7	.826 491	2.33	.870 276	1.92	.956 215	4.23	.043 785	53
8	.826 631	2.32	.870 161	1.90	.956 469	4.23	.043 531	52
9	.826 770	2.33	.870 047	1.90	.956 723	4.23	.043 277	51
10	9.826 910	2.32	9.869 933	1.92	9.956 977	4.23	0.043 023	50
11	.827 049	2.33	.869 818	1.90	.957 231	4.23	.042 769	49
12	.827 189	2.32	.869 704	1.92	.957 485	4.23	.042 515	48
13	.827 328	2.32	.869 589	1.92	.957 739	4.23	.042 261	47
14	.827 467	2.32	.869 474	1.90	.957 993	4.23	.042 007	46
15	9.827 606	2.32	9.869 360	1.92	9.958 247	4.22	0.041 753	45
16	.827 745	2.32	.869 245	1.92	.958 500	4.23	.041 500	44
17	.827 884	2.32	.869 130	1.92	.958 754	4.23	.041 246	43
18	.828 023	2.32	.869 015	1.92	.959 008	4.23	.040 992	42
19	.828 162	2.32	.868 900	1.92	.959 262	4.23	.040 738	41
20	9.828 301	2.30	9.868 785	1.92	9.959 516	4.22	0.040 484	40
21	.828 439	2.32	.868 670	1.92	.959 769	4.23	.040 231	39
22	.828 578	2.30	.868 555	1.92	.960 023	4.23	.039 977	38
23	.828 716	2.32	.868 440	1.93	.960 277	4.22	.039 723	37
24	.828 855	2.30	.868 324	1.92	.960 530	4.23	.039 470	36
25	9.828 993	2.30	9.868 209	1.93	9.960 784	4.23	0.039 216	35
26	.829 131	2.30	.868 093	1.92	.961 038	4.23	.038 962	34
27	.829 269	2.30	.867 978	1.93	.961 292	4.22	.038 708	33
28	.829 407	2.30	.867 862	1.92	.961 545	4.23	.038 455	32
29	.829 545	2.30	.867 747	1.93	.961 799	4.22	.038 201	31
30	9.829 683	2.30	9.867 631	1.93	9.962 052	4.23	0.037 948	30
31	.829 821	2.30	.867 515	1.93	.962 306	4.23	.037 694	29
32	.829 959	2.30	.867 399	1.93	.962 560	4.22	.037 440	28
33	.830 097	2.28	.867 283	1.93	.962 813	4.23	.037 187	27
34	.830 234	2.30	.867 167	1.93	.963 067	4.22	.036 933	26
35	9.830 372	2.28	9.867 051	1.93	9.963 320	4.23	0.036 680	25
36	.830 509	2.28	.866 935	1.93	.963 574	4.23	.036 426	24
37	.830 646	2.30	.866 819	1.93	.963 828	4.22	.036 172	23
38	.830 784	2.28	.866 703	1.95	.964 081	4.23	.035 919	22
39	.830 921	2.28	.866 586	1.93	.964 335	4.22	.035 665	21
40	9.831 058	2.28	9.866 470	1.95	9.964 588	4.23	0.035 412	20
41	.831 195	2.28	.866 353	1.93	.964 842	4.22	.035 158	19
42	.831 332	2.28	.866 237	1.95	.965 095	4.23	.034 905	18
43	.831 469	2.28	.866 120	1.93	.965 349	4.22	.034 651	17
44	.831 606	2.27	.866 004	1.95	.965 602	4.22	.034 398	16
45	9.831 742	2.28	9.865 887	1.95	9.965 855	4.23	0.034 145	15
46	.831 879	2.27	.865 770	1.95	.966 109	4.22	.033 891	14
47	.832 015	2.28	.865 653	1.95	.966 362	4.23	.033 638	13
48	.832 152	2.27	.865 536	1.95	.966 616	4.22	.033 384	12
49	.832 288	2.28	.865 419	1.95	.966 869	4.23	.033 131	11
50	9.832 425	2.27	9.865 302	1.95	9.967 123	4.22	0.032 877	10
51	.832 561	2.27	.865 185	1.95	.967 376	4.22	.032 624	9
52	.832 697	2.27	.865 068	1.97	.967 629	4.23	.032 371	8
53	.832 833	2.27	.864 950	1.95	.967 883	4.22	.032 117	7
54	.832 969	2.27	.864 833	1.95	.968 136	4.22	.031 864	6
55	9.833 105	2.27	9.864 716	1.97	9.968 389	4.23	0.031 611	5
56	.833 241	2.27	.864 598	1.95	.968 643	4.22	.031 357	4
57	.833 377	2.25	.864 481	1.97	.968 896	4.22	.031 104	3
58	.833 512	2.27	.864 363	1.97	.969 149	4.23	.030 851	2
59	.833 648	2.25	.864 245	1.97	.969 403	4.22	.030 597	1
60	9.833 783		9.864 127		9.969 656		0.030 344	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

47°

43°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.833 783	2.27	9.864 127	1.95	9.969 656	4.22	0.030 344	60
1	.833 919	2.25	.864 010	1.97	.969 909	4.22	.030 091	59
2	.834 054	2.25	.863 892	1.97	.970 162	4.23	.029 838	58
3	.834 189	2.27	.863 774	1.97	.970 416	4.22	.029 584	57
4	.834 325	2.25	.863 656	1.97	.970 669	4.22	.029 331	56
5	9.834 460	2.25	9.863 538	1.98	9.970 922	4.22	0.029 078	55
6	.834 595	2.25	.863 419	1.97	.971 175	4.23	.028 825	54
7	.834 730	2.25	.863 301	1.97	.971 429	4.22	.028 571	53
8	.834 865	2.23	.863 183	1.98	.971 682	4.22	.028 318	52
9	.834 999	2.25	.863 064	1.97	.971 935	4.22	.028 065	51
10	9.835 134	2.25	9.862 946	1.98	9.972 188	4.22	0.027 812	50
11	.835 269	2.23	.862 827	1.97	.972 441	4.23	.027 559	49
12	.835 403	2.25	.862 709	1.98	.972 695	4.22	.027 305	48
13	.835 538	2.23	.862 590	1.98	.972 948	4.22	.027 052	47
14	.835 672	2.25	.862 471	1.97	.973 201	4.22	.026 799	46
15	9.835 807	2.23	9.862 353	1.98	9.973 454	4.22	0.026 546	45
16	.835 941	2.23	.862 234	1.98	.973 707	4.22	.026 293	44
17	.836 075	2.23	.862 115	1.98	.973 960	4.22	.026 040	43
18	.836 209	2.23	.861 996	1.98	.974 213	4.22	.025 787	42
19	.836 343	2.23	.861 877	1.98	.974 466	4.23	.025 534	41
20	9.836 477	2.23	9.861 758	2.00	9.974 720	4.22	0.025 280	40
21	.836 611	2.23	.861 638	1.98	.974 973	4.22	.025 027	39
22	.836 745	2.22	.861 519	1.98	.975 226	4.22	.024 774	38
23	.836 878	2.23	.861 400	2.00	.975 479	4.22	.024 521	37
24	.837 012	2.23	.861 280	1.98	.975 732	4.22	.024 268	36
25	9.837 146	2.22	9.861 161	2.00	9.975 985	4.22	0.024 015	35
26	.837 279	2.22	.861 041	1.98	.976 238	4.22	.023 762	34
27	.837 412	2.23	.860 922	2.00	.976 491	4.22	.023 509	33
28	.837 546	2.22	.860 802	2.00	.976 744	4.22	.023 256	32
29	.837 679	2.22	.860 682	2.00	.976 997	4.22	.023 003	31
30	9.837 812	2.22	9.860 562	2.00	9.977 250	4.22	0.022 750	30
31	.837 945	2.22	.860 442	2.00	.977 503	4.22	.022 497	29
32	.838 078	2.22	.860 322	2.00	.977 756	4.22	.022 244	28
33	.838 211	2.22	.860 202	2.00	.978 009	4.22	.021 991	27
34	.838 344	2.22	.860 082	2.00	.978 262	4.22	.021 738	26
35	9.838 477	2.22	9.859 962	2.00	9.978 515	4.22	0.021 485	25
36	.838 610	2.20	.859 842	2.02	.978 768	4.22	.021 232	24
37	.838 742	2.22	.859 721	2.00	.979 021	4.22	.020 979	23
38	.838 875	2.20	.859 601	2.02	.979 274	4.22	.020 726	22
39	.839 007	2.22	.859 480	2.00	.979 527	4.22	.020 473	21
40	9.839 140	2.20	9.859 360	2.02	9.979 780	4.22	0.020 220	20
41	.839 272	2.20	.859 239	2.00	.980 033	4.22	.019 967	19
42	.839 404	2.20	.859 119	2.02	.980 286	4.20	.019 714	18
43	.839 536	2.20	.858 998	2.02	.980 538	4.22	.019 462	17
44	.839 668	2.20	.858 877	2.02	.980 791	4.22	.019 209	16
45	9.839 800	2.20	9.858 756	2.02	9.981 044	4.22	0.018 956	15
46	.839 932	2.20	.858 635	2.02	.981 297	4.22	.018 703	14
47	.840 064	2.20	.858 514	2.02	.981 550	4.22	.018 450	13
48	.840 196	2.20	.858 393	2.02	.981 803	4.22	.018 197	12
49	.840 328	2.18	.858 272	2.02	.982 056	4.22	.017 944	11
50	9.840 459	2.20	9.858 151	2.03	9.982 309	4.22	0.017 691	10
51	.840 591	2.18	.858 029	2.02	.982 562	4.20	.017 438	9
52	.840 722	2.20	.857 908	2.03	.982 814	4.22	.017 186	8
53	.840 854	2.18	.857 786	2.02	.983 067	4.22	.016 933	7
54	.840 985	2.18	.857 665	2.03	.983 320	4.22	.016 680	6
55	9.841 116	2.18	9.857 543	2.02	9.983 573	4.22	0.016 427	5
56	.841 247	2.18	.857 422	2.03	.983 826	4.22	.016 174	4
57	.841 378	2.18	.857 300	2.03	.984 079	4.22	.015 921	3
58	.841 509	2.18	.857 178	2.03	.984 332	4.20	.015 668	2
59	.841 640	2.18	.857 056	2.03	.984 584	4.22	.015 416	1
60	9.841 771		9.856 934		9.984 837		0.015 163	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

46°

44°

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.841 771	2.18	9.856 934	2.03	9.984 837	4.22	0.015 163	60
1	.841 902	2.18	.856 812	2.03	.985 090	4.22	.014 910	59
2	.842 033	2.17	.856 690	2.03	.985 343	4.22	.014 657	58
3	.842 163	2.18	.856 568	2.03	.985 596	4.20	.014 404	57
4	.842 294	2.17	.856 446	2.05	.985 848	4.22	.014 152	56
5	9.842 424	2.18	9.856 323	2.03	9.986 101	4.22	0.013 899	55
6	.842 555	2.17	.856 201	2.05	.986 354	4.22	.013 646	54
7	.842 685	2.17	.856 078	2.03	.986 607	4.22	.013 393	53
8	.842 815	2.18	.855 956	2.05	.986 860	4.20	.013 140	52
9	.842 946	2.17	.855 833	2.03	.987 112	4.22	.012 888	51
10	9.843 076	2.17	9.855 711	2.05	9.987 365	4.22	0.012 635	50
11	.843 206	2.17	.855 588	2.05	.987 618	4.22	.012 382	49
12	.843 336	2.17	.855 465	2.05	.987 871	4.20	.012 129	48
13	.843 466	2.15	.855 342	2.05	.988 123	4.22	.011 877	47
14	.843 595	2.17	.855 219	2.05	.988 376	4.22	.011 624	46
15	9.843 725	2.17	9.855 096	2.05	9.988 629	4.22	0.011 371	45
16	.843 855	2.15	.854 973	2.05	.988 882	4.20	.011 118	44
17	.843 984	2.17	.854 850	2.05	.989 134	4.22	.010 866	43
18	.844 114	2.15	.854 727	2.07	.989 387	4.22	.010 613	42
19	.844 243	2.15	.854 603	2.05	.989 640	4.22	.010 360	41
20	9.844 372	2.17	9.854 480	2.07	9.989 893	4.20	0.010 107	40
21	.844 502	2.15	.854 356	2.05	.990 145	4.22	.009 855	39
22	.844 631	2.15	.854 233	2.07	.990 398	4.22	.009 602	38
23	.844 760	2.15	.854 109	2.05	.990 651	4.20	.009 349	37
24	.844 889	2.15	.853 986	2.07	.990 903	4.22	.009 097	36
25	9.845 018	2.15	9.853 862	2.07	9.991 156	4.22	0.008 844	35
26	.845 147	2.15	.853 738	2.07	.991 409	4.22	.008 591	34
27	.845 276	2.15	.853 614	2.07	.991 662	4.20	.008 338	33
28	.845 405	2.13	.853 490	2.07	.991 914	4.22	.008 086	32
29	.845 533	2.15	.853 366	2.07	.992 167	4.22	.007 833	31
30	9.845 662	2.13	9.853 242	2.07	9.992 420	4.20	0.007 580	30
31	.845 790	2.15	.853 118	2.07	.992 672	4.22	.007 328	29
32	.845 919	2.13	.852 994	2.08	.992 925	4.22	.007 075	28
33	.846 047	2.13	.852 869	2.07	.993 178	4.22	.006 822	27
34	.846 175	2.15	.852 745	2.08	.993 431	4.20	.006 569	26
35	9.846 304	2.13	9.852 620	2.07	9.993 683	4.22	0.006 317	25
36	.846 432	2.13	.852 496	2.08	.993 936	4.22	.006 064	24
37	.846 560	2.13	.852 371	2.07	.994 189	4.20	.005 811	23
38	.846 688	2.13	.852 247	2.08	.994 441	4.22	.005 559	22
39	.846 816	2.13	.852 122	2.08	.994 694	4.22	.005 306	21
40	9.846 944	2.12	9.851 997	2.08	9.994 947	4.20	0.005 053	20
41	.847 071	2.13	.851 872	2.08	.995 199	4.22	.004 801	19
42	.847 199	2.13	.851 747	2.08	.995 452	4.22	.004 548	18
43	.847 327	2.12	.851 622	2.08	.995 705	4.20	.004 295	17
44	.847 454	2.13	.851 497	2.08	.995 957	4.22	.004 043	16
45	9.847 582	2.12	9.851 372	2.10	9.996 210	4.22	0.003 790	15
46	.847 709	2.12	.851 246	2.08	.996 463	4.20	.003 537	14
47	.847 836	2.13	.851 121	2.08	.996 715	4.22	.003 285	13
48	.847 964	2.12	.850 996	2.10	.996 968	4.22	.003 032	12
49	.848 091	2.12	.850 870	2.08	.997 221	4.20	.002 779	11
50	9.848 218	2.12	9.850 745	2.10	9.997 473	4.22	0.002 527	10
51	.848 345	2.12	.850 619	2.10	.997 726	4.22	.002 274	9
52	.848 472	2.12	.850 493	2.08	.997 979	4.20	.002 021	8
53	.848 599	2.12	.850 368	2.10	.998 231	4.22	.001 769	7
54	.848 726	2.10	.850 242	2.10	.998 484	4.22	.001 516	6
55	9.848 852	2.12	9.850 116	2.10	9.998 737	4.20	0.001 263	5
56	.848 979	2.12	.849 990	2.10	.998 989	4.22	.001 011	4
57	.849 106	2.10	.849 864	2.10	.999 242	4.22	.000 758	3
58	.849 232	2.12	.849 738	2.12	.999 495	4.20	.000 505	2
59	.849 359	2.10	.849 611	2.10	.999 747	4.22	.000 253	1
60	9.849 485		9.849 485		0.000 000		0.000 000	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

45°

TABLE XIX

NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS,

FOR EVERY

DEGREE AND MINUTE FROM 0° TO 90°.

	0°				1°				2°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.00000	1.0000	.00000	∞	.01745	.99985	.01746	57.290	.03490	.99939	.03492	28.636	60
1	029	000	029	3437.7	774	984	775	56.351	519	938	521	.399	59
2	058	000	058	1718.9	803	984	804	55.442	548	937	550	.166	58
3	087	000	087	1145.9	832	983	833	54.561	577	936	579	27.937	57
4	116	000	116	859.44	862	983	862	53.709	606	935	609	.712	56
5	.00145	1.0000	.00145	687.55	.01891	.99982	.01891	52.882	.03635	.99934	.03638	27.490	55
6	175	000	175	572.96	920	982	920	.081	664	933	667	.271	54
7	204	000	204	491.11	949	981	949	51.303	693	932	696	.057	53
8	233	000	233	429.72	978	980	978	50.549	723	931	725	26.845	52
9	262	000	262	381.97	.02007	980	.02007	49.816	752	930	754	.637	51
10	.00291	1.0000	.00291	343.77	.02036	.99979	.02036	49.104	.03781	.99929	.03783	26.432	50
11	320	.99999	320	312.52	065	979	066	48.412	810	927	812	.230	49
12	349	999	349	286.48	094	978	095	47.740	839	926	842	.031	48
13	378	999	378	264.44	123	977	124	.085	868	925	871	25.835	47
14	407	999	407	245.55	152	977	153	46.449	897	924	900	.642	46
15	.00436	.99999	.00436	229.18	.02181	.99976	.02182	45.829	.03926	.99923	.03929	25.452	45
16	465	999	465	214.86	211	976	211	.226	955	922	958	.264	44
17	495	999	495	202.22	240	975	240	44.639	984	921	987	.080	43
18	524	999	524	190.98	269	974	269	.066	.04013	919	.04016	24.898	42
19	553	998	553	180.93	298	974	298	43.508	042	918	046	.719	41
20	.00582	.99998	.00582	171.89	.02327	.99973	.02328	42.964	.04071	.99917	.04075	24.542	40
21	611	998	611	163.70	356	972	357	.433	100	916	104	.368	39
22	640	998	640	156.26	385	972	386	41.916	129	915	133	.196	38
23	669	998	669	149.47	414	971	415	.411	159	913	162	.026	37
24	698	998	698	143.24	443	970	444	40.917	188	912	191	23.859	36
25	.00727	.99997	.00727	137.51	.02472	.99969	.02473	40.436	.04217	.99911	.04220	23.695	35
26	756	997	756	132.22	501	969	502	39.965	246	910	250	.532	34
27	785	997	785	127.32	530	968	531	.506	275	909	279	.372	33
28	814	997	815	122.77	560	967	560	.057	304	907	308	.214	32
29	844	996	844	118.54	589	966	589	38.618	333	906	337	.058	31
30	.00873	.99996	.00873	114.59	.02618	.99966	.02619	38.188	.04362	.99905	.04366	22.904	30
31	902	996	902	110.89	647	965	648	37.769	391	904	395	.752	29
32	931	996	931	107.43	676	964	677	.358	420	902	424	.602	28
33	960	995	960	104.17	705	963	706	36.956	449	901	454	.454	27
34	989	995	989	101.11	734	963	735	.563	478	900	483	.308	26
35	.01018	.99995	.01018	98.218	.02763	.99962	.02764	36.178	.04507	.99898	.04512	22.164	25
36	047	995	047	95.489	792	961	793	35.801	536	897	541	.022	24
37	076	994	076	92.908	821	960	822	.431	565	896	570	21.881	23
38	105	994	105	90.463	850	959	851	.070	594	894	599	.743	22
39	134	994	135	88.144	879	959	881	34.715	623	893	628	.606	21
40	.01164	.99993	.01164	85.940	.02908	.99958	.02910	34.368	.04653	.99892	.04658	21.470	20
41	193	993	193	83.844	938	957	939	.027	682	890	687	.337	19
42	222	993	222	81.847	967	956	968	33.694	711	889	716	.205	18
43	251	992	251	79.943	996	955	997	.366	740	888	745	.075	17
44	280	992	280	78.126	.03025	954	.03026	.045	769	886	774	20.946	16
45	.01309	.99991	.01309	76.390	.03054	.99953	.03055	32.730	.04798	.99885	.04803	20.819	15
46	338	991	338	74.729	083	952	084	.421	827	883	833	.693	14
47	367	991	367	73.139	112	952	114	.118	856	882	862	.569	13
48	396	990	396	71.615	141	951	143	31.821	885	881	891	.446	12
49	425	990	425	70.153	170	950	172	.528	914	879	920	.325	11
50	.01454	.99989	.01455	68.750	.03199	.99949	.03201	31.242	.04943	.99878	.04949	20.206	10
51	483	989	484	67.402	228	948	230	30.960	972	876	978	.087	9
52	513	989	513	66.105	257	947	259	.683	.05001	875	.05007	19.970	8
53	542	988	542	64.858	286	946	288	.412	030	873	037	.855	7
54	571	988	571	63.657	316	945	317	.145	059	872	066	.740	6
55	.01600	.99987	.01600	62.499	.03345	.99944	.03346	29.882	.05088	.99870	.05095	19.627	5
56	629	987	629	61.383	374	943	376	.624	117	869	124	.516	4
57	658	986	658	60.306	403	942	405	.371	146	867	153	.405	3
58	687	986	687	59.266	432	941	434	.122	175	866	182	.296	2
59	716	985	716	58.261	461	940	463	28.877	205	864	212	.188	1
60	.01745	.99985	.01746	57.290	.03490	.99939	.03492	28.636	.05234	.99863	.05241	19.081	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	89°				88°				87°				

	3°				4°				5°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.05234	.99863	.05241	19.081	.06976	.99756	.06993	14.301	.08716	.99619	.08749	11.430	60
1	263	861	270	18.976	.07005	754	.07022	.241	745	617	778	.392	59
2	292	860	299	.871	034	752	051	.182	774	614	807	.354	58
3	321	858	328	.768	063	750	080	.124	803	612	837	.316	57
4	350	857	357	.666	092	748	110	.065	831	609	866	.279	56
5	.05379	.99855	.05387	18.564	.07121	.99746	.07139	14.008	.08860	.99607	.08895	11.242	55
6	408	854	416	.464	150	744	168	13.951	889	604	925	.205	54
7	437	852	445	.366	179	742	197	.894	918	602	954	.168	53
8	466	851	474	.268	208	740	227	.838	947	599	983	.132	52
9	495	849	503	.171	237	738	256	.782	976	596	.09013	.095	51
10	.05524	.99847	.05533	18.075	.07266	.99736	.07285	13.727	.09005	.99594	.09042	11.059	50
11	553	846	562	17.980	295	734	314	.672	034	591	071	.024	49
12	582	844	591	.886	324	731	344	.617	063	588	101	10.988	48
13	611	842	620	.793	353	729	373	.563	092	586	130	.953	47
14	640	841	649	.702	382	727	402	.510	121	583	159	.918	46
15	.05669	.99839	.05678	17.611	.07411	.99725	.07431	13.457	.09150	.99580	.09189	10.883	45
16	698	838	708	.521	440	723	461	.404	179	578	218	.848	44
17	727	836	737	.431	469	721	490	.352	208	575	247	.814	43
18	756	834	766	.343	498	719	519	.300	237	572	277	.780	42
19	785	833	795	.256	527	716	548	.248	266	570	306	.746	41
20	.05814	.99831	.05824	17.169	.07556	.99714	.07578	13.197	.09295	.99567	.09335	10.712	40
21	844	829	854	.084	585	712	607	.146	324	564	365	.678	39
22	873	827	883	16.999	614	710	636	.096	353	562	394	.645	38
23	902	826	912	.915	643	708	665	.046	382	559	423	.612	37
24	931	824	941	.832	672	705	695	12.996	411	556	453	.579	36
25	.05960	.99822	.05970	16.750	.07701	.99703	.07724	12.947	.09440	.99553	.09482	10.546	35
26	989	821	999	.668	730	701	753	.898	469	551	511	.514	34
27	.06018	819	.06029	.587	759	699	782	.850	498	548	541	.481	33
28	047	817	058	.507	788	696	812	.801	527	545	570	.449	32
29	076	815	087	.428	817	694	841	.754	556	542	600	.417	31
30	.06105	.99813	.06116	16.350	.07846	.99692	.07870	12.706	.09585	.99540	.09629	10.385	30
31	134	812	145	.272	875	689	899	.659	614	537	658	.354	29
32	163	810	175	.195	904	687	929	.612	642	534	688	.322	28
33	192	808	204	.119	933	685	958	.566	671	531	717	.291	27
34	221	806	233	.043	962	683	987	.520	700	528	746	.260	26
35	.06250	.99804	.06262	15.969	.07991	.99680	.08017	12.474	.09729	.99526	.09776	10.229	25
36	279	803	291	.895	.08020	678	046	.429	758	523	805	.199	24
37	308	801	321	.821	049	676	075	.384	787	520	834	.168	23
38	337	799	350	.748	078	673	104	.339	816	517	864	.138	22
39	366	797	379	.676	107	671	134	.295	845	514	893	.108	21
40	.06395	.99795	.06408	15.605	.08136	.99668	.08163	12.251	.09874	.99511	.09923	10.078	20
41	424	793	438	.534	165	666	192	.207	903	508	952	.048	19
42	453	792	467	.464	194	664	221	.163	932	506	981	.019	18
43	482	790	496	.394	223	661	251	.120	961	503	.10011	9.9893	17
44	511	788	525	.325	252	659	280	.077	990	500	040	.9601	16
45	.06540	.99786	.06554	15.257	.08281	.99657	.08309	12.035	.10019	.99497	.10069	9.9310	15
46	569	784	584	.189	310	654	339	11.992	048	494	099	.9021	14
47	598	782	613	.122	339	652	368	.950	077	491	128	.8734	13
48	627	780	642	.056	368	649	397	.909	106	488	158	.8448	12
49	656	778	671	14.990	397	647	427	.867	135	485	187	.8164	11
50	.06685	.99776	.06700	14.924	.08426	.99644	.08456	11.826	.10164	.99482	.10216	9.7882	10
51	714	774	730	.860	455	642	485	.785	192	479	246	.7601	9
52	743	772	759	.795	484	639	514	.745	221	476	275	.7322	8
53	773	770	788	.732	513	637	544	.705	250	473	305	.7044	7
54	802	768	817	.669	542	635	573	.664	279	470	334	.6768	6
55	.06831	.99766	.06847	14.606	.08571	.99632	.08602	11.625	.10308	.99467	.10363	9.6493	5
56	860	764	876	.544	600	630	632	.585	337	464	393	.6220	4
57	889	762	905	.482	629	627	661	.546	366	461	422	.5949	3
58	918	760	934	.421	658	625	690	.507	395	458	452	.5679	2
59	947	758	963	.361	687	622	720	.468	424	455	481	.5411	1
60	.06976	.99756	.06993	14.301	.08716	.99619	.08749	11.430	.10453	.99452	.10510	9.5144	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	86°				85°				84°				

	6°				7°				8°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.10453	.99452	.10510	9.5144	.12187	.99255	.12278	8.1443	.13917	.99027	.14054	7.1154	60
1	482	449	540	.4878	216	251	308	.1248	946	023	084	.1004	59
2	511	446	569	.4614	245	248	338	.1054	975	019	113	.0855	58
3	540	443	599	.4352	274	244	367	.0860	.14004	015	143	.0706	57
4	569	440	628	.4090	302	240	397	.0667	033	011	173	.0558	56
5	.10597	.99437	.10657	9.3831	.12331	.99237	.12426	8.0476	.14061	.99006	.14202	7.0410	55
6	626	434	687	.3572	360	233	456	.0285	090	002	232	.0264	54
7	655	431	716	.3315	389	230	485	.0095	119	.98998	262	.0117	53
8	684	428	746	.3060	418	226	515	7.9906	148	994	291	6.9972	52
9	713	424	775	.2806	447	222	544	.9718	177	990	321	.9827	51
10	.10742	.99421	.10805	9.2553	.12476	.99219	.12574	7.9530	.14205	.98986	.14351	6.9682	50
11	771	418	834	.2302	504	215	603	.9344	234	982	381	.9538	49
12	800	415	863	.2052	533	211	633	.9158	263	978	410	.9395	48
13	829	412	893	.1803	562	208	662	.8973	292	973	440	.9252	47
14	858	409	922	.1555	591	204	692	.8789	320	969	470	.9110	46
15	.10887	.99406	.10952	9.1309	.12620	.99200	.12722	7.8606	.14349	.98965	.14499	6.8969	45
16	916	402	981	.1065	649	197	751	.8424	378	961	529	.8828	44
17	945	399	.11011	.0821	678	193	781	.8243	407	957	559	.8687	43
18	973	396	040	.0579	706	189	810	.8062	436	953	588	.8548	42
19	.11002	393	070	.0338	735	186	840	.7882	464	948	618	.8408	41
20	.11031	.99390	.11099	9.0098	.12764	.99182	.12869	7.7704	.14493	.98944	.14648	6.8269	40
21	060	386	128	8.9860	793	178	899	.7525	522	940	678	.8131	39
22	089	383	158	.9623	822	175	929	.7348	551	936	707	.7994	38
23	118	380	187	.9387	851	171	958	.7171	580	931	737	.7856	37
24	147	377	217	.9152	880	167	988	.6996	608	927	767	.7720	36
25	.11176	.99374	.11246	8.8919	.12908	.99163	.13017	7.6821	.14637	.98923	.14796	6.7584	35
26	205	370	276	.8686	937	160	047	.6647	666	919	826	.7448	34
27	234	367	305	.8455	966	156	076	.6473	695	914	856	.7313	33
28	263	364	335	.8225	995	152	106	.6301	723	910	886	.7179	32
29	291	360	364	.7996	.13024	148	136	.6129	752	906	915	.7045	31
30	.11320	.99357	.11394	8.7769	.13053	.99144	.13165	7.5958	.14781	.98902	.14945	6.6912	30
31	349	354	423	.7542	081	141	195	.5787	810	897	975	.6779	29
32	378	351	452	.7317	110	137	224	.5618	838	893	.15005	.6646	28
33	407	347	482	.7093	139	133	254	.5449	867	889	034	.6514	27
34	436	344	511	.6870	168	129	284	.5281	896	884	064	.6383	26
35	.11465	.99341	.11541	8.6648	.13197	.99125	.13313	7.5113	.14925	.98880	.15094	6.6252	25
36	494	337	570	.6427	226	122	343	.4947	954	876	124	.6122	24
37	523	334	600	.6208	254	118	372	.4781	982	871	153	.5992	23
38	552	331	629	.5989	283	114	402	.4615	.15011	867	183	.5863	22
39	580	327	659	.5772	312	110	432	.4451	040	863	213	.5734	21
40	.11609	.99324	.11688	8.5555	.13341	.99106	.13461	7.4287	.15069	.98858	.15243	6.5606	20
41	638	320	718	.5340	370	102	491	.4124	097	854	272	.5478	19
42	667	317	747	.5126	399	098	521	.3962	126	849	302	.5350	18
43	696	314	777	.4913	427	094	550	.3800	155	845	332	.5223	17
44	725	310	806	.4701	456	091	580	.3639	184	841	362	.5097	16
45	.11754	.99307	.11836	8.4490	.13485	.99087	.13609	7.3479	.15212	.98836	.15391	6.4971	15
46	783	303	865	.4280	514	083	639	.3319	241	832	421	.4846	14
47	812	300	895	.4071	543	079	669	.3160	270	827	451	.4721	13
48	840	297	924	.3863	572	075	698	.3002	299	823	481	.4596	12
49	869	293	954	.3656	600	071	728	.2844	327	818	511	.4472	11
50	.11898	.99290	.11983	8.3450	.13629	.99067	.13758	7.2687	.15356	.98814	.15540	6.4348	10
51	927	286	.12013	.3245	658	063	787	.2531	385	809	570	.4225	9
52	956	283	042	.3041	687	059	817	.2375	414	805	600	.4103	8
53	985	279	072	.2838	716	055	846	.2220	442	800	630	.3980	7
54	.12014	276	101	.2636	744	051	876	.2066	471	796	660	.3859	6
55	.12043	.99272	.12131	8.2434	.13773	.99047	.13906	7.1912	.15500	.98791	.15689	6.3737	5
56	071	269	160	.2234	802	043	935	.1759	529	787	719	.3617	4
57	100	265	190	.2035	831	039	965	.1607	557	782	749	.3496	3
58	129	262	219	.1837	860	035	995	.1455	586	778	779	.3376	2
59	158	258	249	.1640	889	031	.14024	.1304	615	773	809	.3257	1
60	.12187	.99255	.12278	8.1443	.13917	.99027	.14054	7.1154	.15643	.98769	.15838	6.3138	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	83°				82°				81°				

	9°				10°				11°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.15643	.98769	.15838	6.3138	.17365	.98481	.17633	5.6713	.19081	.98163	.19438	5.1446	60
1	672	764	868	.3019	393	476	663	.6617	109	157	468	.1366	59
2	701	760	898	.2901	422	471	693	.6521	138	152	498	.1286	58
3	730	755	928	.2783	451	466	723	.6425	167	146	529	.1207	57
4	758	751	958	.2666	479	461	753	.6329	195	140	559	.1128	56
5	.15787	.98746	.15988	6.2549	.17508	.98455	.17783	5.6234	.19224	.98135	.19589	5.1049	55
6	816	741	.16017	.2432	537	450	813	.6140	252	129	619	.0970	54
7	845	737	047	.2316	565	445	843	.6045	281	124	649	.0892	53
8	873	732	077	.2200	594	440	873	.5951	309	118	680	.0814	52
9	902	728	107	.2085	623	435	903	.5857	338	112	710	.0736	51
10	.15931	.98723	.16137	6.1970	.17651	.98430	.17933	5.5764	.19366	.98107	.19740	5.0658	50
11	959	718	167	.1856	680	425	963	.5671	395	101	770	.0581	49
12	988	714	196	.1742	708	420	993	.5578	423	096	801	.0504	48
13	.16017	709	226	.1628	737	414	.18023	.5485	452	090	831	.0427	47
14	046	704	256	.1515	766	409	053	.5393	481	084	861	.0350	46
15	.16074	.98700	.16286	6.1402	.17794	.98404	.18083	5.5301	.19509	.98079	.19891	5.0273	45
16	103	695	316	.1290	823	399	113	.5209	538	073	921	.0197	44
17	132	690	346	.1178	852	394	143	.5118	566	067	952	.0121	43
18	160	686	376	.1066	880	389	173	.5026	595	061	982	.0045	42
19	189	681	405	.0955	909	383	203	.4936	623	056	.20012	4.9969	41
20	.16218	.98676	.16435	6.0844	.17937	.98378	.18233	5.4845	.19652	.98050	.20042	4.9894	40
21	246	671	465	.0734	966	373	263	.4755	680	044	073	.9819	39
22	275	667	495	.0624	995	368	293	.4665	709	039	103	.9744	38
23	304	662	525	.0514	.18023	362	323	.4575	737	033	133	.9669	37
24	333	657	555	.0405	052	357	353	.4486	766	027	164	.9594	36
25	.16361	.98652	.16585	6.0296	.18081	.98352	.18384	5.4397	.19794	.98021	.20194	4.9520	35
26	390	648	615	.0188	109	347	414	.4308	823	016	224	.9446	34
27	419	643	645	.0080	138	341	444	.4219	851	010	254	.9372	33
28	447	638	674	5.9972	166	336	474	.4131	880	004	285	.9298	32
29	476	633	704	.9865	195	331	504	.4043	908	.97998	315	.9225	31
30	.16505	.98629	.16734	5.9758	.18224	.98325	.18534	5.3955	.19937	.97992	.20345	4.9152	30
31	533	624	764	.9651	252	320	564	.3868	965	987	376	.9078	29
32	562	619	794	.9545	281	315	594	.3781	994	981	406	.9006	28
33	591	614	824	.9439	309	310	624	.3694	.20022	975	436	.8933	27
34	620	609	854	.9333	338	304	654	.3607	051	969	466	.8860	26
35	.16648	.98604	.16884	5.9228	.18367	.98299	.18684	5.3521	.20079	.97963	.20497	4.8788	25
36	677	600	914	.9124	395	294	714	.3435	108	958	527	.8716	24
37	706	595	944	.9019	424	288	745	.3349	136	952	557	.8644	23
38	734	590	974	.8915	452	283	775	.3263	165	946	588	.8573	22
39	763	585	.17004	.8811	481	277	805	.3178	193	940	618	.8501	21
40	.16792	.98580	.17033	5.8708	.18509	.98272	.18835	5.3093	.20222	.97934	.20648	4.8430	20
41	820	575	063	.8605	538	267	865	.3008	250	928	679	.8359	19
42	849	570	093	.8502	567	261	895	.2924	279	922	709	.8288	18
43	878	565	123	.8400	595	256	925	.2839	307	916	739	.8218	17
44	906	561	153	.8298	624	250	955	.2755	336	910	770	.8147	16
45	.16935	.98556	.17183	5.8197	.18652	.98245	.18986	5.2672	.20364	.97905	.20800	4.8077	15
46	964	551	213	.8095	681	240	.19016	.2588	393	899	830	.8007	14
47	992	546	243	.7994	710	234	046	.2505	421	893	861	.7937	13
48	.17021	541	273	.7894	738	229	076	.2422	450	887	891	.7867	12
49	050	536	303	.7794	767	223	106	.2339	478	881	921	.7798	11
50	.17078	.98531	.17333	5.7694	.18795	.98218	.19136	5.2257	.20507	.97875	.20952	4.7729	10
51	107	526	363	.7594	824	212	166	.2174	535	869	982	.7659	9
52	136	521	393	.7495	852	207	197	.2092	563	863	.21013	.7591	8
53	164	516	423	.7396	881	201	227	.2011	592	857	043	.7522	7
54	193	511	453	.7297	910	196	257	.1929	620	851	073	.7453	6
55	.17222	.98506	.17483	5.7199	.18938	.98190	.19287	5.1848	.20649	.97845	.21104	4.7385	5
56	250	501	513	.7101	967	185	317	.1767	677	839	134	.7317	4
57	279	496	543	.7004	995	179	347	.1686	706	833	164	.7249	3
58	308	491	573	.6906	.19024	174	378	.1606	734	827	195	.7181	2
59	336	486	603	.6809	052	168	408	.1526	763	821	225	.7114	1
60	.17365	.98481	.17633	5.6713	.19081	.98163	.19438	5.1446	.20791	.97815	.21256	4.7046	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	80°				79°				78°				

	12°				13°				14°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.20791	.97815	.21256	4.7046	.22495	.97437	.23087	4.3315	.24192	.97030	.24933	4.0108	60
1	820	809	286	.6979	523	430	117	.3257	220	023	964	.0058	59
2	848	803	316	.6912	552	424	148	.3200	249	015	995	.0009	58
3	877	797	347	.6845	580	417	179	.3143	277	008	.25026	3.9959	57
4	905	791	377	.6779	608	411	209	.3086	305	001	056	.9910	56
5	.20933	.97784	.21408	4.6712	.22637	.97404	.23240	4.3029	.24333	.96994	.25087	3.9861	55
6	962	778	438	.6646	665	398	271	.2972	362	987	118	.9812	54
7	990	772	469	.6580	693	391	301	.2916	390	980	149	.9763	53
8	.21019	766	499	.6514	722	384	332	.2859	418	973	180	.9714	52
9	047	760	529	.6448	750	378	363	.2803	446	966	211	.9665	51
10	.21076	.97754	.21560	4.6382	.22778	.97371	.23393	4.2747	.24474	.96959	.25242	3.9617	50
11	104	748	590	.6317	807	365	424	.2691	503	952	273	.9568	49
12	132	742	621	.6252	835	358	455	.2635	531	945	304	.9520	48
13	161	735	651	.6187	863	351	485	.2580	559	937	335	.9471	47
14	189	729	682	.6122	892	345	516	.2524	587	930	366	.9423	46
15	.21218	.97723	.21712	4.6057	.22920	.97338	.23547	4.2468	.24615	.96923	.25397	3.9375	45
16	246	717	743	.5993	948	331	578	.2413	644	916	428	.9327	44
17	275	711	773	.5928	977	325	608	.2358	672	909	459	.9279	43
18	303	705	804	.5864	.23005	318	639	.2303	700	902	490	.9232	42
19	331	698	834	.5800	033	311	670	.2248	728	894	521	.9184	41
20	.21360	.97692	.21864	4.5736	.23062	.97304	.23700	4.2193	.24756	.96887	.25552	3.9136	40
21	388	686	895	.5673	090	298	731	.2139	784	880	583	.9089	39
22	417	680	925	.5609	118	291	762	.2084	813	873	614	.9042	38
23	445	673	956	.5546	146	284	793	.2030	841	866	645	.8995	37
24	474	667	986	.5483	175	278	823	.1976	869	858	676	.8947	36
25	.21502	.97661	.22017	4.5420	.23203	.97271	.23854	4.1922	.24897	.96851	.25707	3.8900	35
26	530	655	047	.5357	231	264	885	.1868	925	844	738	.8854	34
27	559	648	078	.5294	260	257	916	.1814	954	837	769	.8807	33
28	587	642	108	.5232	288	251	946	.1760	982	829	800	.8760	32
29	616	636	139	.5169	316	244	977	.1706	.25010	822	831	.8714	31
30	.21644	.97630	.22169	4.5107	.23345	.97237	.24008	4.1653	.25038	.96815	.25862	3.8667	30
31	672	623	200	.5045	373	230	039	.1600	066	807	893	.8621	29
32	701	617	231	.4983	401	223	069	.1547	094	800	924	.8575	28
33	729	611	261	.4922	429	217	100	.1493	122	793	955	.8528	27
34	758	604	292	.4860	458	210	131	.1441	151	786	986	.8482	26
35	.21786	.97598	.22322	4.4799	.23486	.97203	.24162	4.1388	.25179	.96778	.26017	3.8436	25
36	814	592	353	.4737	514	196	193	.1335	207	771	048	.8391	24
37	843	585	383	.4676	542	189	223	.1282	235	764	079	.8345	23
38	871	579	414	.4615	571	182	254	.1230	263	756	110	.8299	22
39	899	573	444	.4555	599	176	285	.1178	291	749	141	.8254	21
40	.21928	.97566	.22475	4.4494	.23627	.97169	.24316	4.1126	.25320	.96742	.26172	3.8208	20
41	956	560	505	.4434	656	162	347	.1074	348	734	203	.8163	19
42	985	553	536	.4373	684	155	377	.1022	376	727	235	.8118	18
43	.22013	547	567	.4313	712	148	408	.0970	404	719	266	.8073	17
44	041	541	597	.4253	740	141	439	.0918	432	712	297	.8028	16
45	.22070	.97534	.22628	4.4194	.23769	.97134	.24470	4.0867	.25460	.96705	.26328	3.7983	15
46	098	528	658	.4134	797	127	501	.0815	488	697	359	.7938	14
47	126	521	689	.4075	825	120	532	.0764	516	690	390	.7893	13
48	155	515	719	.4015	853	113	562	.0713	545	682	421	.7848	12
49	183	508	750	.3956	882	106	593	.0662	573	675	452	.7804	11
50	.22212	.97502	.22781	4.3897	.23910	.97100	.24624	4.0611	.25601	.96667	.26483	3.7760	10
51	240	496	811	.3838	938	093	655	.0560	629	660	515	.7715	9
52	268	489	842	.3779	966	086	686	.0509	657	653	546	.7671	8
53	297	483	872	.3721	995	079	717	.0459	685	645	577	.7627	7
54	325	476	903	.3662	.24023	072	747	.0408	713	638	608	.7583	6
55	.22353	.97470	.22934	4.3604	.24051	.97065	.24778	4.0358	.25741	.96630	.26639	3.7539	5
56	382	463	964	.3546	079	058	809	.0308	769	623	670	.7495	4
57	410	457	995	.3488	108	051	840	.0257	798	615	701	.7451	3
58	438	450	.23026	.3430	136	044	871	.0207	826	608	733	.7408	2
59	467	444	056	.3372	164	037	902	.0158	854	600	764	.7364	1
60	.22495	.97437	.23087	4.3315	.24192	.97030	.24933	4.0108	.25882	.96593	.26795	3.7321	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	77°				76°				75°				

	15°				16°				17°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.25882	.96593	.26795	3.7321	.27564	.96126	.28675	3.4874	.29237	.95630	.30573	3.2709	60
1	910	585	826	.7277	592	118	706	.4836	265	622	605	.2675	59
2	938	578	857	.7234	620	110	738	.4798	293	613	637	.2641	58
3	966	570	888	.7191	648	102	769	.4760	321	605	669	.2607	57
4	994	562	920	.7148	676	094	801	.4722	348	596	700	.2573	56
5	.26022	.96555	.26951	3.7105	.27704	.96086	.28832	3.4684	.29376	.95588	.30732	3.2539	55
6	050	547	982	.7062	731	078	864	.4646	404	579	764	.2506	54
7	079	540	.27013	.7019	759	070	895	.4608	432	571	796	.2472	53
8	107	532	044	.6976	787	062	927	.4570	460	562	828	.2438	52
9	135	524	076	.6933	815	054	958	.4533	487	554	860	.2405	51
10	.26163	.96517	.27107	3.6891	.27843	.96046	.28990	3.4495	.29515	.95545	.30891	3.2371	50
11	191	509	138	.6848	871	037	.29021	.4458	543	536	923	.2338	49
12	219	502	169	.6806	899	029	053	.4420	571	528	955	.2305	48
13	247	494	201	.6764	927	021	084	.4383	599	519	987	.2272	47
14	275	486	232	.6722	955	013	116	.4346	626	511	.31019	.2238	46
15	.26303	.96479	.27263	3.6680	.27983	.96005	.29147	3.4308	.29654	.95502	.31051	3.2205	45
16	331	471	294	.6638	.28011	.95997	179	.4271	682	493	083	.2172	44
17	359	463	326	.6596	039	989	210	.4234	710	485	115	.2139	43
18	387	456	357	.6554	067	981	242	.4197	737	476	147	.2106	42
19	415	448	388	.6512	095	972	274	.4160	765	467	178	.2073	41
20	.26443	.96440	.27419	3.6470	.28123	.95964	.29305	3.4124	.29793	.95459	.31210	3.2041	40
21	471	433	451	.6429	150	956	337	.4087	821	450	242	.2008	39
22	500	425	482	.6387	178	948	368	.4050	849	441	274	.1975	38
23	528	417	513	.6346	206	940	400	.4014	876	433	306	.1943	37
24	556	410	545	.6305	234	931	432	.3977	904	424	338	.1910	36
25	.26584	.96402	.27576	3.6264	.28262	.95923	.29463	3.3941	.29932	.95415	.31370	3.1878	35
26	612	394	607	.6222	290	915	495	.3904	960	407	402	.1845	34
27	640	386	638	.6181	318	907	526	.3868	987	398	434	.1813	33
28	668	379	670	.6140	346	898	558	.3832	.30015	389	466	.1780	32
29	696	371	701	.6100	374	890	590	.3796	043	380	498	.1748	31
30	.26724	.96363	.27732	3.6059	.28402	.95882	.29621	3.3759	.30071	.95372	.31530	3.1716	30
31	752	355	764	.6018	429	874	653	.3723	098	363	562	.1684	29
32	780	347	795	.5978	457	865	685	.3687	126	354	594	.1652	28
33	808	340	826	.5937	485	857	716	.3652	154	345	626	.1620	27
34	836	332	858	.5897	513	849	748	.3616	182	337	658	.1588	26
35	.26864	.96324	.27889	3.5856	.28541	.95841	.29780	3.3580	.30209	.95328	.31690	3.1556	25
36	892	316	921	.5816	569	832	811	.3544	237	319	722	.1524	24
37	920	308	952	.5776	597	824	843	.3509	265	310	754	.1492	23
38	948	301	983	.5736	625	816	875	.3473	292	301	786	.1460	22
39	976	293	.28015	.5696	652	807	906	.3438	320	293	818	.1429	21
40	.27004	.96285	.28046	3.5656	.28680	.95799	.29938	3.3402	.30348	.95284	.31850	3.1397	20
41	032	277	077	.5616	708	791	970	.3367	376	275	882	.1366	19
42	060	269	109	.5576	736	782	.30001	.3332	403	266	914	.1334	18
43	088	261	140	.5536	764	774	033	.3297	431	257	946	.1303	17
44	116	253	172	.5497	792	766	065	.3261	459	248	978	.1271	16
45	.27144	.96246	.28203	3.5457	.28820	.95757	.30097	3.3226	.30486	.95240	.32010	3.1240	15
46	172	238	234	.5418	847	749	128	.3191	514	231	042	.1209	14
47	200	230	266	.5379	875	740	160	.3156	542	222	074	.1178	13
48	228	222	297	.5339	903	732	192	.3122	570	213	106	.1146	12
49	256	214	329	.5300	931	724	224	.3087	597	204	139	.1115	11
50	.27284	.96206	.28360	3.5261	.28959	.95715	.30255	3.3052	.30625	.95195	.32171	3.1084	10
51	312	198	391	.5222	987	707	287	.3017	653	186	203	.1053	9
52	340	190	423	.5183	.29015	698	319	.2983	680	177	235	.1022	8
53	368	182	454	.5144	042	690	351	.2948	708	168	267	.0991	7
54	396	174	486	.5105	070	681	382	.2914	736	159	299	.0961	6
55	.27424	.96166	.28517	3.5067	.29098	.95673	.30414	3.2879	.30763	.95150	.32331	3.0930	5
56	452	158	549	.5028	126	664	446	.2845	791	142	363	.0899	4
57	480	150	580	.4989	154	656	478	.2811	819	133	396	.0868	3
58	508	142	612	.4951	182	647	509	.2777	846	124	428	.0838	2
59	536	134	643	.4912	209	639	541	.2743	874	115	460	.0807	1
60	.27564	.96126	.28675	3.4874	.29237	.95630	.30573	3.2709	.30902	.95106	.32492	3.0777	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	74°				73°				72°				

	18°				19°				20°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.30902	.95106	.32492	3.0777	.32557	.94552	.34433	2.9042	.34202	.93969	.36397	2.7475	60
1	929	097	524	.0746	584	542	465	.9015	229	959	430	.7450	59
2	957	088	556	.0716	612	533	498	.8987	257	949	463	.7425	58
3	985	079	588	.0686	639	523	530	.8960	284	939	496	.7400	57
4	.31012	070	621	.0655	667	514	563	.8933	311	929	529	.7376	56
5	.31040	.95061	.32653	3.0625	.32694	.94504	.34596	2.8905	.34339	.93919	.36562	2.7351	55
6	068	052	685	.0595	722	495	628	.8878	366	909	595	.7326	54
7	095	043	717	.0565	749	485	661	.8851	393	899	628	.7302	53
8	123	033	749	.0535	777	476	693	.8824	421	889	661	.7277	52
9	151	024	782	.0505	804	466	726	.8797	448	879	694	.7253	51
10	.31178	.95015	.32814	3.0475	.32832	.94457	.34758	2.8770	.34475	.93869	.36727	2.7228	50
11	206	006	846	.0445	859	447	791	.8743	503	859	760	.7204	49
12	233	.94997	878	.0415	887	438	824	.8716	530	849	793	.7179	48
13	261	988	911	.0385	914	428	856	.8689	557	839	826	.7155	47
14	289	979	943	.0356	942	418	889	.8662	584	829	859	.7130	46
15	.31316	.94970	.32975	3.0326	.32969	.94409	.34922	2.8636	.34612	.93819	.36892	2.7106	45
16	344	961	.33007	.0296	997	399	954	.8609	639	809	925	.7082	44
17	372	952	040	.0267	.33024	390	987	.8582	666	799	958	.7058	43
18	399	943	072	.0237	051	380	.35020	.8556	694	789	991	.7034	42
19	427	933	104	.0208	079	370	052	.8529	721	779	.37024	.7009	41
20	.31454	.94924	.33136	3.0178	.33106	.94361	.35085	2.8502	.34748	.93769	.37057	2.6985	40
21	482	915	169	.0149	134	351	118	.8476	775	759	090	.6961	39
22	510	906	201	.0120	161	342	150	.8449	803	748	123	.6937	38
23	537	897	233	.0090	189	332	183	.8423	830	738	157	.6913	37
24	565	888	266	.0061	216	322	216	.8397	857	728	190	.6889	36
25	.31593	.94878	.33298	3.0032	.33244	.94313	.35248	2.8370	.34884	.93718	.37223	2.6865	35
26	620	869	330	.0003	271	303	281	.8344	912	708	256	.6841	34
27	648	860	363	2.9974	298	293	314	.8318	939	698	289	.6818	33
28	675	851	395	.9945	326	284	346	.8291	966	688	322	.6794	32
29	703	842	427	.9916	353	274	379	.8265	993	677	355	.6770	31
30	.31730	.94832	.33460	2.9887	.33381	.94264	.35412	2.8239	.35021	.93667	.37388	2.6746	30
31	758	823	492	.9858	408	254	445	.8213	048	657	422	.6723	29
32	786	814	524	.9829	436	245	477	.8187	075	647	455	.6699	28
33	813	805	557	.9800	463	235	510	.8161	102	637	488	.6675	27
34	841	795	589	.9772	490	225	543	.8135	130	626	521	.6652	26
35	.31868	.94786	.33621	2.9743	.33518	.94215	.35576	2.8109	.35157	.93616	.37554	2.6628	25
36	896	777	654	.9714	545	206	608	.8083	184	606	588	.6605	24
37	923	768	686	.9686	573	196	641	.8057	211	596	621	.6581	23
38	951	758	718	.9657	600	186	674	.8032	239	585	654	.6558	22
39	979	749	751	.9629	627	176	707	.8006	266	575	687	.6534	21
40	.32006	.94740	.33783	2.9600	.33655	.94167	.35740	2.7980	.35293	.93565	.37720	2.6511	20
41	034	730	816	.9572	682	157	772	.7955	320	555	754	.6488	19
42	061	721	848	.9544	710	147	805	.7929	347	544	787	.6464	18
43	089	712	881	.9515	737	137	838	.7903	375	534	820	.6441	17
44	116	702	913	.9487	764	127	871	.7878	402	524	853	.6418	16
45	.32144	.94693	.33945	2.9459	.33792	.94118	.35904	2.7852	.35429	.93514	.37887	2.6395	15
46	171	684	978	.9431	819	108	937	.7827	456	503	920	.6371	14
47	199	674	.34010	.9403	846	098	969	.7801	484	493	953	.6348	13
48	227	665	043	.9375	874	088	.36002	.7776	511	483	986	.6325	12
49	254	656	075	.9347	901	078	035	.7751	538	472	.38020	.6302	11
50	.32282	.94646	.34108	2.9319	.33929	.94068	.36068	2.7725	.35565	.93462	.38053	2.6279	10
51	309	637	140	.9291	956	058	101	.7700	592	452	086	.6256	9
52	337	627	173	.9263	983	049	134	.7675	619	441	120	.6233	8
53	364	618	205	.9235	.34011	039	167	.7650	647	431	153	.6210	7
54	392	609	238	.9208	038	029	199	.7625	674	420	186	.6187	6
55	.32419	.94599	.34270	2.9180	.34065	.94019	.36232	2.7600	.35701	.93410	.38220	2.6165	5
56	447	590	303	.9152	093	009	265	.7575	728	400	253	.6142	4
57	474	580	335	.9125	120	.93999	298	.7550	755	389	286	.6119	3
58	502	571	368	.9097	147	989	331	.7525	782	379	320	.6096	2
59	529	561	400	.9070	175	979	364	.7500	810	368	353	.6074	1
60	.32557	.94552	.34433	2.9042	.34202	.93969	.36397	2.7475	.35837	.93358	.38386	2.6051	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	71°				70°				69°				

	21°				22°				23°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.35837	.93358	.38386	2.6051	.37461	.92718	.40403	2.4751	.39073	.92050	.42447	2.3559	60
1	864	348	420	.6028	488	707	436	.4730	100	039	482	.3539	59
2	891	337	453	.6006	515	697	470	.4709	127	028	516	.3520	58
3	918	327	487	.5983	542	686	504	.4689	153	016	551	.3501	57
4	945	316	520	.5961	569	675	538	.4668	180	005	585	.3483	56
5	.35973	.93306	.38553	2.5938	.37595	.92664	.40572	2.4648	.39207	.91994	.42619	2.3464	55
6	.36000	295	587	.5916	622	653	606	.4627	234	982	654	.3445	54
7	027	285	620	.5893	649	642	640	.4606	260	971	688	.3426	53
8	054	274	654	.5871	676	631	674	.4586	287	959	722	.3407	52
9	081	264	687	.5848	703	620	707	.4566	314	948	757	.3388	51
10	.36108	.93253	.38721	2.5826	.37730	.92609	.40741	2.4545	.39341	.91936	.42791	2.3369	50
11	135	243	754	.5804	757	598	775	.4525	367	925	826	.3351	49
12	162	232	787	.5782	784	587	809	.4504	394	914	860	.3332	48
13	190	222	821	.5759	811	576	843	.4484	421	902	894	.3313	47
14	217	211	854	.5737	838	565	877	.4464	448	891	929	.3294	46
15	.36244	.93201	.38888	2.5715	.37865	.92554	.40911	2.4443	.39474	.91879	.42963	2.3276	45
16	271	190	921	.5693	892	543	945	.4423	501	868	998	.3257	44
17	298	180	955	.5671	919	532	979	.4403	528	856	.43032	.3238	43
18	325	169	988	.5649	946	521	.41013	.4383	555	845	067	.3220	42
19	352	159	.39022	.5627	973	510	047	.4362	581	833	101	.3201	41
20	.36379	.93148	.39055	2.5605	.37999	.92499	.41081	2.4342	.39608	.91822	.43136	2.3183	40
21	406	137	089	.5583	.38026	488	115	.4322	635	810	170	.3164	39
22	434	127	122	.5561	053	477	149	.4302	661	799	205	.3146	38
23	461	116	156	.5539	080	466	183	.4282	688	787	239	.3127	37
24	488	106	190	.5517	107	455	217	.4262	715	775	274	.3109	36
25	.36515	.93095	.39223	2.5495	.38134	.92444	.41251	2.4242	.39741	.91764	.43308	2.3090	35
26	542	084	257	.5473	161	432	285	.4222	768	752	343	.3072	34
27	569	074	290	.5452	188	421	319	.4202	795	741	378	.3053	33
28	596	063	324	.5430	215	410	353	.4182	822	729	412	.3035	32
29	623	052	357	.5408	241	399	387	.4162	848	718	447	.3017	31
30	.36650	.93042	.39391	2.5386	.38268	.92388	.41421	2.4142	.39875	.91706	.43481	2.2998	30
31	677	031	425	.5365	295	377	455	.4122	902	694	516	.2980	29
32	704	020	458	.5343	322	366	490	.4102	928	683	550	.2962	28
33	731	010	492	.5322	349	355	524	.4083	955	671	585	.2944	27
34	758	.92999	526	.5300	376	343	558	.4063	982	660	620	.2925	26
35	.36785	.92988	.39559	2.5279	.38403	.92332	.41592	2.4043	.40008	.91648	.43654	2.2907	25
36	812	978	593	.5257	430	321	626	.4023	035	636	689	.2889	24
37	839	967	626	.5236	456	310	660	.4004	062	625	724	.2871	23
38	867	956	660	.5214	483	299	694	.3984	088	613	758	.2853	22
39	894	945	694	.5193	510	287	728	.3964	115	601	793	.2835	21
40	.36921	.92935	.39727	2.5172	.38537	.92276	.41763	2.3945	.40141	.91590	.43828	2.2817	20
41	948	924	761	.5150	564	265	797	.3925	168	578	862	.2799	19
42	975	913	795	.5129	591	254	831	.3906	195	566	897	.2781	18
43	.37002	902	829	.5108	617	243	865	.3886	221	555	932	.2763	17
44	029	892	862	.5086	644	231	899	.3867	248	543	966	.2745	16
45	.37056	.92881	.39896	2.5065	.38671	.92220	.41933	2.3847	.40275	.91531	.44001	2.2727	15
46	083	870	930	.5044	698	209	968	.3828	301	519	036	.2709	14
47	110	859	963	.5023	725	198	.42002	.3808	328	508	071	.2691	13
48	137	849	997	.5002	752	186	036	.3789	355	496	105	.2673	12
49	164	838	.40031	.4981	778	175	070	.3770	381	484	140	.2655	11
50	.37191	.92827	.40065	2.4960	.38805	.92164	.42105	2.3750	.40408	.91472	.44175	2.2637	10
51	218	816	098	.4939	832	152	139	.3731	434	461	210	.2620	9
52	245	805	132	.4918	859	141	173	.3712	461	449	244	.2602	8
53	272	794	166	.4897	886	130	207	.3693	488	437	279	.2584	7
54	299	784	200	.4876	912	119	242	.3673	514	425	314	.2566	6
55	.37326	.92773	.40234	2.4855	.38939	.92107	.42276	2.3654	.40541	.91414	.44349	2.2549	5
56	353	762	267	.4834	966	096	310	.3635	567	402	384	.2531	4
57	380	751	301	.4813	993	085	345	.3616	594	390	418	.2513	3
58	407	740	335	.4792	.39020	073	379	.3597	621	378	453	.2496	2
59	434	729	369	.4772	046	062	413	.3578	647	366	488	.2478	1
60	.37461	.92718	.40403	2.4751	.39073	.92050	.42447	2.3559	.40674	.91355	.44523	2.2460	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	68°				67°				66°				

	24°				25°				26°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.40674	.91355	.44523	2.2460	.42262	.90631	.46631	2.1445	.43837	.89879	.48773	2.0503	60
1	700	343	558	.2443	288	618	666	.1429	863	867	809	.0488	59
2	727	331	593	.2425	315	606	702	.1413	889	854	845	.0473	58
3	753	319	627	.2408	341	594	737	.1396	916	841	881	.0458	57
4	780	307	662	.2390	367	582	772	.1380	942	828	917	.0443	56
5	.40806	.91295	.44697	2.2373	.42394	.90569	.46808	2.1364	.43968	.89816	.48953	2.0428	55
6	833	283	732	.2355	420	557	843	.1348	994	803	989	.0413	54
7	860	272	767	.2338	446	545	879	.1332	.44020	790	.49026	.0398	53
8	886	260	802	.2320	473	532	914	.1315	046	777	062	.0383	52
9	913	248	837	.2303	499	520	950	.1299	072	764	098	.0368	51
10	.40939	.91236	.44872	2.2286	.42525	.90507	.46985	2.1283	.44098	.89752	.49134	2.0353	50
11	966	224	907	.2268	552	495	.47021	.1267	124	739	170	.0338	49
12	992	212	942	.2251	578	483	056	.1251	151	726	206	.0323	48
13	.41019	200	977	.2234	604	470	092	.1235	177	713	242	.0308	47
14	045	188	.45012	.2216	631	458	128	.1219	203	700	278	.0293	46
15	.41072	.91176	.45047	2.2199	.42657	.90446	.47163	2.1203	.44229	.89687	.49315	2.0278	45
16	098	164	082	.2182	683	433	199	.1187	255	674	351	.0263	44
17	125	152	117	.2165	709	421	234	.1171	281	662	387	.0248	43
18	151	140	152	.2148	736	408	270	.1155	307	649	423	.0233	42
19	178	128	187	.2130	762	396	305	.1139	333	636	459	.0219	41
20	.41204	.91116	.45222	2.2113	.42788	.90383	.47341	2.1123	.44359	.89623	.49495	2.0204	40
21	231	104	257	.2096	815	371	377	.1107	385	610	532	.0189	39
22	257	092	292	.2079	841	358	412	.1092	411	597	568	.0174	38
23	284	080	327	.2062	867	346	448	.1076	437	584	604	.0160	37
24	310	068	362	.2045	894	334	483	.1060	464	571	640	.0145	36
25	.41337	.91056	.45397	2.2028	.42920	.90321	.47519	2.1044	.44490	.89558	.49677	2.0130	35
26	363	044	432	.2011	946	309	555	.1028	516	545	713	.0115	34
27	390	032	467	.1994	972	296	590	.1013	542	532	749	.0101	33
28	416	020	502	.1977	999	284	626	.0997	568	519	786	.0086	32
29	443	008	538	.1960	.43025	271	662	.0981	594	506	822	.0072	31
30	.41469	.90996	.45573	2.1943	.43051	.90259	.47698	2.0965	.44620	.89493	.49858	2.0057	30
31	496	984	608	.1926	077	246	733	.0950	646	480	894	.0042	29
32	522	972	643	.1909	104	233	769	.0934	672	467	931	.0028	28
33	549	960	678	.1892	130	221	805	.0918	698	454	967	.0013	27
34	575	948	713	.1876	156	208	840	.0903	724	441	.50004	1.9999	26
35	.41602	.90936	.45748	2.1859	.43182	.90196	.47876	2.0887	.44750	.89428	.50040	1.9984	25
36	628	924	784	.1842	209	183	912	.0872	776	415	076	.9970	24
37	655	911	819	.1825	235	171	948	.0856	802	402	113	.9955	23
38	681	899	854	.1808	261	158	984	.0840	828	389	149	.9941	22
39	707	887	889	.1792	287	146	.48019	.0825	854	376	185	.9926	21
40	.41734	.90875	.45924	2.1775	.43313	.90133	.48055	2.0809	.44880	.89363	.50222	1.9912	20
41	760	863	960	.1758	340	120	091	.0794	906	350	258	.9897	19
42	787	851	995	.1742	366	108	127	.0778	932	337	295	.9883	18
43	813	839	.46030	.1725	392	095	163	.0763	958	324	331	.9868	17
44	840	826	065	.1708	418	082	198	.0748	984	311	368	.9854	16
45	.41866	.90814	.46101	2.1692	.43445	.90070	.48234	2.0732	.45010	.89298	.50404	1.9840	15
46	892	802	136	.1675	471	057	270	.0717	036	285	441	.9825	14
47	919	790	171	.1659	497	045	306	.0701	062	272	477	.9811	13
48	945	778	206	.1642	523	032	342	.0686	088	259	514	.9797	12
49	972	766	242	.1625	549	019	378	.0671	114	245	550	.9782	11
50	.41998	.90753	.46277	2.1609	.43575	.90007	.48414	2.0655	.45140	.89232	.50587	1.9768	10
51	.42024	741	312	.1592	602	.89994	450	.0640	166	219	623	.9754	9
52	051	729	348	.1576	628	981	486	.0625	192	206	660	.9740	8
53	077	717	383	.1560	654	968	521	.0609	218	193	696	.9725	7
54	104	704	418	.1543	680	956	557	.0594	243	180	733	.9711	6
55	.42130	.90692	.46454	2.1527	.43706	.89943	.48593	2.0579	.45269	.89167	.50769	1.9697	5
56	156	680	489	.1510	733	930	629	.0564	295	153	806	.9683	4
57	183	668	525	.1494	759	918	665	.0549	321	140	843	.9669	3
58	209	655	560	.1478	785	905	701	.0533	347	127	879	.9654	2
59	235	643	595	.1461	811	892	737	.0518	373	114	916	.9640	1
60	.42262	.90631	.46631	2.1445	.43837	.89879	.48773	2.0503	.45399	.89101	.50953	1.9626	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	65°				64°				63°				

	27°				28°				29°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.45399	.89101	.50953	1.9626	.46947	.88295	.53171	1.8807	.48481	.87462	.55431	1.8040	60
1	425	087	989	.9612	973	281	208	.8794	506	448	469	.8028	59
2	451	074	.51026	.9598	999	267	246	.8781	532	434	507	.8016	58
3	477	061	063	.9584	.47024	254	283	.8768	557	420	545	.8003	57
4	503	048	099	.9570	050	240	320	.8755	583	406	583	.7991	56
5	.45529	.89035	.51136	1.9556	.47076	.88226	.53358	1.8741	.48608	.87391	.55621	1.7979	55
6	554	021	173	.9542	101	213	395	.8728	634	377	659	.7966	54
7	580	008	209	.9528	127	199	432	.8715	659	363	697	.7954	53
8	606	.88995	246	.9514	153	185	470	.8702	684	349	736	.7942	52
9	632	981	283	.9500	178	172	507	.8689	710	335	774	.7930	51
10	.45658	.88968	.51319	1.9486	.47204	.88158	.53545	1.8676	.48735	.87321	.55812	1.7917	50
11	684	955	356	.9472	229	144	582	.8663	761	306	850	.7905	49
12	710	942	393	.9458	255	130	620	.8650	786	292	888	.7893	48
13	736	928	430	.9444	281	117	657	.8637	811	278	926	.7881	47
14	762	915	467	.9430	306	103	694	.8624	837	264	964	.7868	46
15	.45787	.88902	.51503	1.9416	.47332	.88089	.53732	1.8611	.48862	.87250	.56003	1.7856	45
16	813	888	540	.9402	358	075	769	.8598	888	235	041	.7844	44
17	839	875	577	.9388	383	062	807	.8585	913	221	079	.7832	43
18	865	862	614	.9375	409	048	844	.8572	938	207	117	.7820	42
19	891	848	651	.9361	434	034	882	.8559	964	193	156	.7808	41
20	.45917	.88835	.51688	1.9347	.47460	.88020	.53920	1.8546	.48989	.87178	.56194	1.7796	40
21	942	822	724	.9333	486	006	957	.8533	.49014	164	232	.7783	39
22	968	808	761	.9319	511	.87993	995	.8520	040	150	270	.7771	38
23	994	795	798	.9306	537	979	.54032	.8507	065	136	309	.7759	37
24	.46020	782	835	.9292	562	965	070	.8495	090	121	347	.7747	36
25	.46046	.88768	.51872	1.9278	.47588	.87951	.54107	1.8482	.49116	.87107	.56385	1.7735	35
26	072	755	909	.9265	614	937	145	.8469	141	093	424	.7723	34
27	097	741	946	.9251	639	923	183	.8456	166	079	462	.7711	33
28	123	728	983	.9237	665	909	220	.8443	192	064	501	.7699	32
29	149	715	.52020	.9223	690	896	258	.8430	217	050	539	.7687	31
30	.46175	.88701	.52057	1.9210	.47716	.87882	.54296	1.8418	.49242	.87036	.56577	1.7675	30
31	201	688	094	.9196	741	868	333	.8405	268	021	616	.7663	29
32	226	674	131	.9183	767	854	371	.8392	293	007	654	.7651	28
33	252	661	168	.9169	793	840	409	.8379	318	.86993	693	.7639	27
34	278	647	205	.9155	818	826	446	.8367	344	978	731	.7627	26
35	.46304	.88634	.52242	1.9142	.47844	.87812	.54484	1.8354	.49369	.86964	.56769	1.7615	25
36	330	620	279	.9128	869	798	522	.8341	394	949	808	.7603	24
37	355	607	316	.9115	895	784	560	.8329	419	935	846	.7591	23
38	381	593	353	.9101	920	770	597	.8316	445	921	885	.7579	22
39	407	580	390	.9088	946	756	635	.8303	470	906	923	.7567	21
40	.46433	.88566	.52427	1.9074	.47971	.87743	.54673	1.8291	.49495	.86892	.56962	1.7556	20
41	458	553	464	.9061	997	729	711	.8278	521	878	.57000	.7544	19
42	484	539	501	.9047	.48022	715	748	.8265	546	863	039	.7532	18
43	510	526	538	.9034	048	701	786	.8253	571	849	078	.7520	17
44	536	512	575	.9020	073	687	824	.8240	596	834	116	.7508	16
45	.46561	.88499	.52613	1.9007	.48099	.87673	.54862	1.8228	.49622	.86820	.57155	1.7496	15
46	587	485	650	.8993	124	659	900	.8215	647	805	193	.7485	14
47	613	472	687	.8980	150	645	938	.8202	672	791	232	.7473	13
48	639	458	724	.8967	175	631	975	.8190	697	777	271	.7461	12
49	664	445	761	.8953	201	617	.55013	.8177	723	762	309	.7449	11
50	.46690	.88431	.52798	1.8940	.48226	.87603	.55051	1.8165	.49748	.86748	.57348	1.7437	10
51	716	417	836	.8927	252	589	089	.8152	773	733	386	.7426	9
52	742	404	873	.8913	277	575	127	.8140	798	719	425	.7414	8
53	767	390	910	.8900	303	561	165	.8127	824	704	464	.7402	7
54	793	377	947	.8887	328	546	203	.8115	849	690	503	.7391	6
55	.46819	.88363	.52985	1.8873	.48354	.87532	.55241	1.8103	.49874	.86675	.57541	1.7379	5
56	844	349	.53022	.8860	379	518	279	.8090	899	661	580	.7367	4
57	870	336	059	.8847	405	504	317	.8078	924	646	619	.7355	3
58	896	322	096	.8834	430	490	355	.8065	950	632	657	.7344	2
59	921	308	134	.8820	456	476	393	.8053	975	617	696	.7332	1
60	.46947	.88295	.53171	1.8807	.48481	.87462	.55431	1.8040	.50000	.86603	.57735	1.7321	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	62°				61°				60°				

	30°				31°				32°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.50000	.86603	.57735	1.7321	.51504	.85717	.60086	1.6643	.52992	.84805	.62487	1.6003	60
1	025	588	774	.7309	529	702	126	.6632	.53017	789	527	.5993	59
2	050	573	813	.7297	554	687	165	.6621	041	774	568	.5983	58
3	076	559	851	.7286	579	672	205	.6610	066	759	608	.5972	57
4	101	544	890	.7274	604	657	245	.6599	091	743	649	.5962	56
5	.50126	.86530	.57929	1.7262	.51628	.85642	.60284	1.6588	.53115	.84728	.62689	1.5952	55
6	151	515	968	.7251	653	627	324	.6577	140	712	730	.5941	54
7	176	501	.58007	.7239	678	612	364	.6566	164	697	770	.5931	53
8	201	486	046	.7228	703	597	403	.6555	189	681	811	.5921	52
9	227	471	085	.7216	728	582	443	.6545	214	666	852	.5911	51
10	.50252	.86457	.58124	1.7205	.51753	.85567	.60483	1.6534	.53238	.84650	.62892	1.5900	50
11	277	442	162	.7193	778	551	522	.6523	263	635	933	.5890	49
12	302	427	201	.7182	803	536	562	.6512	288	619	973	.5880	48
13	327	413	240	.7170	828	521	602	.6501	312	604	.63014	.5869	47
14	352	398	279	.7159	852	506	642	.6490	337	588	055	.5859	46
15	.50377	.86384	.58318	1.7147	.51877	.85491	.60681	1.6479	.53361	.84573	.63095	1.5849	45
16	403	369	357	.7136	902	476	721	.6469	386	557	136	.5839	44
17	428	354	396	.7124	927	461	761	.6458	411	542	177	.5829	43
18	453	340	435	.7113	952	446	801	.6447	435	526	217	.5818	42
19	478	325	474	.7102	977	431	841	.6436	460	511	258	.5808	41
20	.50503	.86310	.58513	1.7090	.52002	.85416	.60881	1.6426	.53484	.84495	.63299	1.5798	40
21	528	295	552	.7079	026	401	921	.6415	509	480	340	.5788	39
22	553	281	591	.7067	051	385	960	.6404	534	464	380	.5778	38
23	578	266	631	.7056	076	370	.61000	.6393	558	448	421	.5768	37
24	603	251	670	.7045	101	355	040	.6383	583	433	462	.5757	36
25	.50628	.86237	.58709	1.7033	.52126	.85340	.61080	1.6372	.53607	.84417	.63503	1.5747	35
26	654	222	748	.7022	151	325	120	.6361	632	402	544	.5737	34
27	679	207	787	.7011	175	310	160	.6351	656	386	584	.5727	33
28	704	192	826	.6999	200	294	200	.6340	681	370	625	.5717	32
29	729	178	865	.6988	225	279	240	.6329	705	355	666	.5707	31
30	.50754	.86163	.58905	1.6977	.52250	.85264	.61280	1.6319	.53730	.84339	.63707	1.5697	30
31	779	148	944	.6965	275	249	320	.6308	754	324	748	.5687	29
32	804	133	983	.6954	299	234	360	.6297	779	308	789	.5677	28
33	829	119	.59022	.6943	324	218	400	.6287	804	292	830	.5667	27
34	854	104	061	.6932	349	203	440	.6276	828	277	871	.5657	26
35	.50879	.86089	.59101	1.6920	.52374	.85188	.61480	1.6265	.53853	.84261	.63912	1.5647	25
36	904	074	140	.6909	399	173	520	.6255	877	245	953	.5637	24
37	929	059	179	.6898	423	157	561	.6244	902	230	994	.5627	23
38	954	045	218	.6887	448	142	601	.6234	926	214	.64035	.5617	22
39	979	030	258	.6875	473	127	641	.6223	951	198	076	.5607	21
40	.51004	.86015	.59297	1.6864	.52498	.85112	.61681	1.6212	.53975	.84182	.64117	1.5597	20
41	029	000	336	.6853	522	096	721	.6202	.54000	167	158	.5587	19
42	054	.85985	376	.6842	547	081	761	.6191	024	151	199	.5577	18
43	079	970	415	.6831	572	066	801	.6181	049	135	240	.5567	17
44	104	956	454	.6820	597	051	842	.6170	073	120	281	.5557	16
45	.51129	.85941	.59494	1.6808	.52621	.85035	.61882	1.6160	.54097	.84104	.64322	1.5547	15
46	154	926	533	.6797	646	020	922	.6149	122	088	363	.5537	14
47	179	911	573	.6786	671	005	962	.6139	146	072	404	.5527	13
48	204	896	612	.6775	696	.84989	.62003	.6128	171	057	446	.5517	12
49	229	881	651	.6764	720	974	043	.6118	195	041	487	.5507	11
50	.51254	.85866	.59691	1.6753	.52745	.84959	.62083	1.6107	.54220	.84025	.64528	1.5497	10
51	279	851	730	.6742	770	943	124	.6097	244	009	569	.5487	9
52	304	836	770	.6731	794	928	164	.6087	269	.83994	610	.5477	8
53	329	821	809	.6720	819	913	204	.6076	293	978	652	.5468	7
54	354	806	849	.6709	844	897	245	.6066	317	962	693	.5458	6
55	.51379	.85792	.59888	1.6698	.52869	.84882	.62285	1.6055	.54342	.83946	.64734	1.5448	5
56	404	777	928	.6687	893	866	325	.6045	366	930	775	.5438	4
57	429	762	967	.6676	918	851	366	.6034	391	915	817	.5428	3
58	454	747	.60007	.6665	943	836	406	.6024	415	899	858	.5418	2
59	479	732	046	.6654	967	820	446	.6014	440	883	899	.5408	1
60	.51504	.85717	.60086	1.6643	.52992	.84805	.62487	1.6003	.54464	.83867	.64941	1.5399	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	59°				58°				57°				

	33°				34°				35°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.54464	.83867	.64941	1.5399	.55919	.82904	.67451	1.4826	.57358	.81915	.70021	1.4281	60
1	488	851	982	.5389	943	887	493	.4816	381	899	064	.4273	59
2	513	835	.65024	.5379	968	871	536	.4807	405	882	107	.4264	58
3	537	819	065	.5369	992	855	578	.4798	429	865	151	.4255	57
4	561	804	106	.5359	.56016	839	620	.4788	453	848	194	.4246	56
5	.54586	.83788	.65148	1.5350	.56040	.82822	.67663	1.4779	.57477	.81832	.70238	1.4237	55
6	610	772	189	.5340	064	806	705	.4770	501	815	281	.4229	54
7	635	756	231	.5330	088	790	748	.4761	524	798	325	.4220	53
8	659	740	272	.5320	112	773	790	.4751	548	782	368	.4211	52
9	683	724	314	.5311	136	757	832	.4742	572	765	412	.4202	51
10	.54708	.83708	.65355	1.5301	.56160	.82741	.67875	1.4733	.57596	.81748	.70455	1.4193	50
11	732	692	397	.5291	184	724	917	.4724	619	731	499	.4185	49
12	756	676	438	.5282	208	708	960	.4715	643	714	542	.4176	48
13	781	660	480	.5272	232	692	.68002	.4705	667	698	586	.4167	47
14	805	645	521	.5262	256	675	045	.4696	691	681	629	.4158	46
15	.54829	.83629	.65563	1.5253	.56280	.82659	.68088	1.4687	.57715	.81664	.70673	1.4150	45
16	854	613	604	.5243	305	643	130	.4678	738	647	717	.4141	44
17	878	597	646	.5233	329	626	173	.4669	762	631	760	.4132	43
18	902	581	688	.5224	353	610	215	.4659	786	614	804	.4124	42
19	927	565	729	.5214	377	593	258	.4650	810	597	848	.4115	41
20	.54951	.83549	.65771	1.5204	.56401	.82577	.68301	1.4641	.57833	.81580	.70891	1.4106	40
21	975	533	813	.5195	425	561	343	.4632	857	563	935	.4097	39
22	999	517	854	.5185	449	544	386	.4623	881	546	979	.4089	38
23	.55024	501	896	.5175	473	528	429	.4614	904	530	.71023	.4080	37
24	048	485	938	.5166	497	511	471	.4605	928	513	066	.4071	36
25	.55072	.83469	.65980	1.5156	.56521	.82495	.68514	1.4596	.57952	.81496	.71110	1.4063	35
26	097	453	.66021	.5147	545	478	557	.4586	976	479	154	.4054	34
27	121	437	063	.5137	569	462	600	.4577	999	462	198	.4045	33
28	145	421	105	.5127	593	446	642	.4568	.58023	445	242	.4037	32
29	169	405	147	.5118	617	429	685	.4559	047	428	285	.4028	31
30	.55194	.83389	.66189	1.5108	.56641	.82413	.68728	1.4550	.58070	.81412	.71329	1.4019	30
31	218	373	230	.5099	665	396	771	.4541	094	395	373	.4011	29
32	242	356	272	.5089	689	380	814	.4532	118	378	417	.4002	28
33	266	340	314	.5080	713	363	857	.4523	141	361	461	.3994	27
34	291	324	356	.5070	736	347	900	.4514	165	344	505	.3985	26
35	.55315	.83308	.66398	1.5061	.56760	.82330	.68942	1.4505	.58189	.81327	.71549	1.3976	25
36	339	292	440	.5051	784	314	985	.4496	212	310	593	.3968	24
37	363	276	482	.5042	808	297	.69028	.4487	236	293	637	.3959	23
38	388	260	524	.5032	832	281	071	.4478	260	276	681	.3951	22
39	412	244	566	.5023	856	264	114	.4469	283	259	725	.3942	21
40	.55436	.83228	.66608	1.5013	.56880	.82248	.69157	1.4460	.58307	.81242	.71769	1.3934	20
41	460	212	650	.5004	904	231	200	.4451	330	225	813	.3925	19
42	484	195	692	.4994	928	214	243	.4442	354	208	857	.3916	18
43	509	179	734	.4985	952	198	286	.4433	378	191	901	.3908	17
44	533	163	776	.4975	976	181	329	.4424	401	174	946	.3899	16
45	.55557	.83147	.66818	1.4966	.57000	.82165	.69372	1.4415	.58425	.81157	.71990	1.3891	15
46	581	131	860	.4957	024	148	416	.4406	449	140	.72034	.3882	14
47	605	115	902	.4947	047	132	459	.4397	472	123	078	.3874	13
48	630	098	944	.4938	071	115	502	.4388	496	106	122	.3865	12
49	654	082	986	.4928	095	098	545	.4379	519	089	167	.3857	11
50	.55678	.83066	.67028	1.4919	.57119	.82082	.69588	1.4370	.58543	.81072	.72211	1.3848	10
51	702	050	071	.4910	143	065	631	.4361	567	055	255	.3840	9
52	726	034	113	.4900	167	048	675	.4352	590	038	299	.3831	8
53	750	017	155	.4891	191	032	718	.4344	614	021	344	.3823	7
54	775	001	197	.4882	215	015	761	.4335	637	004	388	.3814	6
55	.55799	.82985	.67239	1.4872	.57238	.81999	.69804	1.4326	.58661	.80987	.72432	1.3806	5
56	823	969	282	.4863	262	982	847	.4317	684	970	477	.3798	4
57	847	953	324	.4854	286	965	891	.4308	708	953	521	.3789	3
58	871	936	366	.4844	310	949	934	.4299	731	936	565	.3781	2
59	895	920	409	.4835	334	932	977	.4290	755	919	610	.3772	1
60	.55919	.82904	.67451	1.4826	.57358	.81915	.70021	1.4281	.58779	.80902	.72654	1.3764	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	56°				55°				54°				

M.	36° Sin.	36° Cos.	36° Tan.	36° Cot.	37° Sin.	37° Cos.	37° Tan.	37° Cot.	38° Sin.	38° Cos.	38° Tan.	38° Cot.	
0	.58779	.80902	.72654	1.3764	.60182	.79864	.75355	1.3270	.61566	.78801	.78129	1.2799	60
1	802	885	699	.3755	205	846	401	.3262	589	783	175	.2792	59
2	826	867	743	.3747	228	829	447	.3254	612	765	222	.2784	58
3	849	850	788	.3739	251	811	492	.3246	635	747	269	.2776	57
4	873	833	832	.3730	274	793	538	.3238	658	729	316	.2769	56
5	.58896	.80816	.72877	1.3722	.60298	.79776	.75584	1.3230	.61681	.78711	.78363	1.2761	55
6	920	799	921	.3713	321	758	629	.3222	704	694	410	.2753	54
7	943	782	966	.3705	344	741	675	.3214	726	676	457	.2746	53
8	967	765	.73010	.3697	367	723	721	.3206	749	658	504	.2738	52
9	990	748	055	.3688	390	706	767	.3198	772	640	551	.2731	51
10	.59014	.80730	.73100	1.3680	.60414	.79688	.75812	1.3190	.61795	.78622	.78598	1.2723	50
11	037	713	144	.3672	437	671	858	.3182	818	604	645	.2715	49
12	061	696	189	.3663	460	653	904	.3175	841	586	692	.2708	48
13	084	679	234	.3655	483	635	950	.3167	864	568	739	.2700	47
14	108	662	278	.3647	506	618	996	.3159	887	550	786	.2693	46
15	.59131	.80644	.73323	1.3638	.60529	.79600	.76042	1.3151	.61909	.78532	.78834	1.2685	45
16	154	627	368	.3630	553	583	088	.3143	932	514	881	.2677	44
17	178	610	413	.3622	576	565	134	.3135	955	496	928	.2670	43
18	201	593	457	.3613	599	547	180	.3127	978	478	975	.2662	42
19	225	576	502	.3605	622	530	226	.3119	.62001	460	.79022	.2655	41
20	.59248	.80558	.73547	1.3597	.60645	.79512	.76272	1.3111	.62024	.78442	.79070	1.2647	40
21	272	541	592	.3588	668	494	318	.3103	046	424	117	.2640	39
22	295	524	637	.3580	691	477	364	.3095	069	405	164	.2632	38
23	318	507	681	.3572	714	459	410	.3087	092	387	212	.2624	37
24	342	489	726	.3564	738	441	456	.3079	115	369	259	.2617	36
25	.59365	.80472	.73771	1.3555	.60761	.79424	.76502	1.3072	.62138	.78351	.79306	1.2609	35
26	389	455	816	.3547	784	406	548	.3064	160	333	354	.2602	34
27	412	438	861	.3539	807	388	594	.3056	183	315	401	.2594	33
28	436	420	906	.3531	830	371	640	.3048	206	297	449	.2587	32
29	459	403	951	.3522	853	353	686	.3040	229	279	496	.2579	31
30	.59482	.80386	.73996	1.3514	.60876	.79335	.76733	1.3032	.62251	.78261	.79544	1.2572	30
31	506	368	.74041	.3506	899	318	779	.3024	274	243	591	.2564	29
32	529	351	086	.3498	922	300	825	.3017	297	225	639	.2557	28
33	552	334	131	.3490	945	282	871	.3009	320	206	686	.2549	27
34	576	316	176	.3481	968	264	918	.3001	342	188	734	.2542	26
35	.59599	.80299	.74221	1.3473	.60991	.79247	.76964	1.2993	.62365	.78170	.79781	1.2534	25
36	622	282	267	.3465	.61015	229	.77010	.2985	388	152	829	.2527	24
37	646	264	312	.3457	038	211	057	.2977	411	134	877	.2519	23
38	669	247	357	.3449	061	193	103	.2970	433	116	924	.2512	22
39	693	230	402	.3440	084	176	149	.2962	456	098	972	.2504	21
40	.59716	.80212	.74447	1.3432	.61107	.79158	.77196	1.2954	.62479	.78079	.80020	1.2497	20
41	739	195	492	.3424	130	140	242	.2946	502	061	067	.2489	19
42	763	178	538	.3416	153	122	289	.2938	524	043	115	.2482	18
43	786	160	583	.3408	176	105	335	.2931	547	025	163	.2475	17
44	809	143	628	.3400	199	087	382	.2923	570	007	211	.2467	16
45	.59832	.80125	.74674	1.3392	.61222	.79069	.77428	1.2915	.62592	.77988	.80258	1.2460	15
46	856	108	719	.3384	245	051	475	.2907	615	970	306	.2452	14
47	879	091	764	.3375	268	033	521	.2900	638	952	354	.2445	13
48	902	073	810	.3367	291	016	568	.2892	660	934	402	.2437	12
49	926	056	855	.3359	314	.78998	615	.2884	683	916	450	.2430	11
50	.59949	.80038	.74900	1.3351	.61337	.78980	.77661	1.2876	.62706	.77897	.80498	1.2423	10
51	972	021	946	.3343	360	962	708	.2869	728	879	546	.2415	9
52	995	003	991	.3335	383	944	754	.2861	751	861	594	.2408	8
53	.60019	.79986	.75037	.3327	406	926	801	.2853	774	843	642	.2401	7
54	042	968	082	.3319	429	908	848	.2846	796	824	690	.2393	6
55	.60065	.79951	.75128	1.3311	.61451	.78891	.77895	1.2838	.62819	.77806	.80738	1.2386	5
56	089	934	173	.3303	474	873	941	.2830	842	788	786	.2378	4
57	112	916	219	.3295	497	855	988	.2822	864	769	834	.2371	3
58	135	899	264	.3287	520	837	.78035	.2815	887	751	882	.2364	2
59	158	881	310	.3278	543	819	082	.2807	909	733	930	.2356	1
60	.60182	.79864	.75355	1.3270	.61566	.78801	.78129	1.2799	.62932	.77715	.80978	1.2349	0
	53° Cos.	53° Sin.	53° Cot.	53° Tan.	52° Cos.	52° Sin.	52° Cot.	52° Tan.	51° Cos.	51° Sin.	51° Cot.	51° Tan.	M.

	39°				40°				41°				
M.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	
0	.62932	.77715	.80978	1.2349	.64279	.76604	.83910	1.1918	.65606	.75471	.86929	1.1504	60
1	955	696	.81027	.2342	301	586	960	.1910	628	452	980	.1497	59
2	977	678	075	.2334	323	567	.84009	.1903	650	433	.87031	.1490	58
3	.63000	660	123	.2327	346	548	059	.1896	672	414	082	.1483	57
4	022	641	171	.2320	368	530	108	.1889	694	395	133	.1477	56
5	.63045	.77623	.81220	1.2312	.64390	.76511	.84158	1.1882	.65716	.75375	.87184	1.1470	55
6	068	605	268	.2305	412	492	208	.1875	738	356	236	.1463	54
7	090	586	316	.2298	435	473	258	.1868	759	337	287	.1456	53
8	113	568	364	.2290	457	455	307	.1861	781	318	338	.1450	52
9	135	550	413	.2283	479	436	357	.1854	803	299	389	.1443	51
10	.63158	.77531	.81461	1.2276	.64501	.76417	.84407	1.1847	.65825	.75280	.87441	1.1436	50
11	180	513	510	.2268	524	398	457	.1840	847	261	492	.1430	49
12	203	494	558	.2261	546	380	507	.1833	869	241	543	.1423	48
13	225	476	606	.2254	568	361	556	.1826	891	222	595	.1416	47
14	248	458	655	.2247	590	342	606	.1819	913	203	646	.1410	46
15	.63271	.77439	.81703	1.2239	.64612	.76323	.84656	1.1812	.65935	.75184	.87698	1.1403	45
16	293	421	752	.2232	635	304	706	.1806	956	165	749	.1396	44
17	316	402	800	.2225	657	286	756	.1799	978	146	801	.1389	43
18	338	384	849	.2218	679	267	806	.1792	.66000	126	852	.1383	42
19	361	366	898	.2210	701	248	856	.1785	022	107	904	.1376	41
20	.63383	.77347	.81946	1.2203	.64723	.76229	.84906	1.1778	.66044	.75088	.87955	1.1369	40
21	406	329	995	.2196	746	210	956	.1771	066	069	.88007	.1363	39
22	428	310	.82044	.2189	768	192	.85006	.1764	088	050	059	.1356	38
23	451	292	092	.2181	790	173	057	.1757	109	030	110	.1349	37
24	473	273	141	.2174	812	154	107	.1750	131	011	162	.1343	36
25	.63496	.77255	.82190	1.2167	.64834	.76135	.85157	1.1743	.66153	.74992	.88214	1.1336	35
26	518	236	238	.2160	856	116	207	.1736	175	973	265	.1329	34
27	540	218	287	.2153	878	097	257	.1729	197	953	317	.1323	33
28	563	199	336	.2145	901	078	308	.1722	218	934	369	.1316	32
29	585	181	385	.2138	923	059	358	.1715	240	915	421	.1310	31
30	.63608	.77162	.82434	1.2131	.64945	.76041	.85408	1.1708	.66262	.74896	.88473	1.1303	30
31	630	144	483	.2124	967	022	458	.1702	284	876	524	.1296	29
32	653	125	531	.2117	989	003	509	.1695	306	857	576	.1290	28
33	675	107	580	.2109	.65011	.75984	559	.1688	327	838	628	.1283	27
34	698	088	629	.2102	033	965	609	.1681	349	818	680	.1276	26
35	.63720	.77070	.82678	1.2095	.65055	.75946	.85660	1.1674	.66371	.74799	.88732	1.1270	25
36	742	051	727	.2088	077	927	710	.1667	393	780	784	.1263	24
37	765	033	776	.2081	100	908	761	.1660	414	760	836	.1257	23
38	787	014	825	.2074	122	889	811	.1653	436	741	888	.1250	22
39	810	.76996	874	.2066	144	870	862	.1647	458	722	940	.1243	21
40	.63832	.76977	.82923	1.2059	.65166	.75851	.85912	1.1640	.66480	.74703	.88992	1.1237	20
41	854	959	972	.2052	188	832	963	.1633	501	683	.89045	.1230	19
42	877	940	.83022	.2045	210	813	.86014	.1626	523	664	097	.1224	18
43	899	921	071	.2038	232	794	064	.1619	545	644	149	.1217	17
44	922	903	120	.2031	254	775	115	.1612	566	625	201	.1211	16
45	.63944	.76884	.83169	1.2024	.65276	.75756	.86166	1.1606	.66588	.74606	.89253	1.1204	15
46	966	866	218	.2017	298	738	216	.1599	610	586	306	.1197	14
47	989	847	268	.2009	320	719	267	.1592	632	567	358	.1191	13
48	.64011	828	317	.2002	342	700	318	.1585	653	548	410	.1184	12
49	033	810	366	.1995	364	680	368	.1578	675	528	463	.1178	11
50	.64056	.76791	.83415	1.1988	.65386	.75661	.86419	1.1571	.66697	.74509	.89515	1.1171	10
51	078	772	465	.1981	408	642	470	.1565	718	489	567	.1165	9
52	100	754	514	.1974	430	623	521	.1558	740	470	620	.1158	8
53	123	735	564	.1967	452	604	572	.1551	762	451	672	.1152	7
54	145	717	613	.1960	474	585	623	.1544	783	431	725	.1145	6
55	.64167	.76698	.83662	1.1953	.65496	.75566	.86674	1.1538	.66805	.74412	.89777	1.1139	5
56	190	679	712	.1946	518	547	725	.1531	827	392	830	.1132	4
57	212	661	761	.1939	540	528	776	.1524	848	373	883	.1126	3
58	234	642	811	.1932	562	509	827	.1517	870	353	935	.1119	2
59	256	623	860	.1925	584	490	878	.1510	891	334	988	.1113	1
60	.64279	.76604	.83910	1.1918	.65606	.75471	.86929	1.1504	.66913	.74314	.90040	1.1106	0
	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	M.
	50°				49°				48°				

M.	42° Sin.	42° Cos.	42° Tan.	42° Cot.	43° Sin.	43° Cos.	43° Tan.	43° Cot.	44° Sin.	44° Cos.	44° Tan.	44° Cot.	
0	.66913	.74314	.90040	1.1106	.68200	.73135	.93252	1.0724	.69466	.71934	.96569	1.0355	60
1	935	295	093	.1100	221	116	306	.0717	487	914	625	.0349	59
2	956	276	146	.1093	242	096	360	.0711	508	894	681	.0343	58
3	978	256	199	.1087	264	076	415	.0705	529	873	738	.0337	57
4	999	237	251	.1080	285	056	469	.0699	549	853	794	.0331	56
5	.67021	.74217	.90304	1.1074	.68306	.73036	.93524	1.0692	.69570	.71833	.96850	1.0325	55
6	043	198	357	.1067	327	016	578	.0686	591	813	907	.0319	54
7	064	178	410	.1061	349	.72996	633	.0680	612	792	963	.0313	53
8	086	159	463	.1054	370	976	688	.0674	633	772	.97020	.0307	52
9	107	139	516	.1048	391	957	742	.0668	654	752	076	.0301	51
10	.67129	.74120	.90569	1.1041	.68412	.72937	.93797	1.0661	.69675	.71732	.97133	1.0295	50
11	151	100	621	.1035	434	917	852	.0655	696	711	189	.0289	49
12	172	080	674	.1028	455	897	906	.0649	717	691	246	.0283	48
13	194	061	727	.1022	476	877	961	.0643	737	671	302	.0277	47
14	215	041	781	.1016	497	857	.94016	.0637	758	650	359	.0271	46
15	.67237	.74022	.90834	1.1009	.68518	.72837	.94071	1.0630	.69779	.71630	.97416	1.0265	45
16	258	002	887	.1003	539	817	125	.0624	800	610	472	.0259	44
17	280	.73983	940	.0996	561	797	180	.0618	821	590	529	.0253	43
18	301	963	993	.0990	582	777	235	.0612	842	569	586	.0247	42
19	323	944	.91046	.0983	603	757	290	.0606	862	549	643	.0241	41
20	.67344	.73924	.91099	1.0977	.68624	.72737	.94345	1.0599	.69883	.71529	.97700	1.0235	40
21	366	904	153	.0971	645	717	400	.0593	904	508	756	.0230	39
22	387	885	206	.0964	666	697	455	.0587	925	488	813	.0224	38
23	409	865	259	.0958	688	677	510	.0581	946	468	870	.0218	37
24	430	846	313	.0951	709	657	565	.0575	966	447	927	.0212	36
25	.67452	.73826	.91366	1.0945	.68730	.72637	.94620	1.0569	.69987	.71427	.97984	1.0206	35
26	473	806	419	.0939	751	617	676	.0562	.70008	407	.98041	.0200	34
27	495	787	473	.0932	772	597	731	.0556	029	386	098	.0194	33
28	516	767	526	.0926	793	577	786	.0550	049	366	155	.0188	32
29	538	747	580	.0919	814	557	841	.0544	070	345	213	.0182	31
30	.67559	.73728	.91633	1.0913	.68835	.72537	.94896	1.0538	.70091	.71325	.98270	1.0176	30
31	580	708	687	.0907	857	517	952	.0532	112	305	327	.0170	29
32	602	688	740	.0900	878	497	.95007	.0526	132	284	384	.0164	28
33	623	669	794	.0894	899	477	062	.0519	153	264	441	.0158	27
34	645	649	847	.0888	920	457	118	.0513	174	243	499	.0152	26
35	.67666	.73629	.91901	1.0881	.68941	.72437	.95173	1.0507	.70195	.71223	.98556	1.0147	25
36	688	610	955	.0875	962	417	229	.0501	215	203	613	.0141	24
37	709	590	.92008	.0869	983	397	284	.0495	236	182	671	.0135	23
38	730	570	062	.0862	.69004	377	340	.0489	257	162	728	.0129	22
39	752	551	116	.0856	025	357	395	.0483	277	141	786	.0123	21
40	.67773	.73531	.92170	1.0850	.69046	.72337	.95451	1.0477	.70298	.71121	.98843	1.0117	20
41	795	511	224	.0843	067	317	506	.0470	319	100	901	.0111	19
42	816	491	277	.0837	088	297	562	.0464	339	080	958	.0105	18
43	837	472	331	.0831	109	277	618	.0458	360	059	.99016	.0099	17
44	859	452	385	.0824	130	257	673	.0452	381	039	073	.0094	16
45	.67880	.73432	.92439	1.0818	.69151	.72236	.95729	1.0446	.70401	.71019	.99131	1.0088	15
46	901	413	493	.0812	172	216	785	.0440	422	.70998	189	.0082	14
47	923	393	547	.0805	193	196	841	.0434	443	978	247	.0076	13
48	944	373	601	.0799	214	176	897	.0428	463	957	304	.0070	12
49	965	353	655	.0793	235	156	952	.0422	484	937	362	.0064	11
50	.67987	.73333	.92709	1.0786	.69256	.72136	.96008	1.0416	.70505	.70916	.99420	1.0058	10
51	.68008	314	763	.0780	277	116	064	.0410	525	896	478	.0052	9
52	029	294	817	.0774	298	095	120	.0404	546	875	536	.0047	8
53	051	274	872	.0768	319	075	176	.0398	567	855	594	.0041	7
54	072	254	926	.0761	340	055	232	.0392	587	834	652	.0035	6
55	.68093	.73234	.92980	1.0755	.69361	.72035	.96288	1.0385	.70608	.70813	.99710	1.0029	5
56	115	215	.93034	.0749	382	015	344	.0379	628	793	768	.0023	4
57	136	195	088	.0742	403	.71995	400	.0373	649	772	826	.0017	3
58	157	175	143	.0736	424	974	457	.0367	670	752	884	.0012	2
59	179	155	197	.0730	445	954	513	.0361	690	731	942	.0006	1
60	.68200	.73135	.93252	1.0724	.69466	.71934	.96569	1.0355	.70711	.70711	1.0000	1.0000	0
	47° Cos.	47° Sin.	47° Cot.	47° Tan.	46° Cos.	46° Sin.	46° Cot.	46° Tan.	45° Cos.	45° Sin.	45° Cot.	45° Tan.	M.

M.	0°		1°		2°		3°		4°		M.
M.	Sin.	Tan.	Sin.	Tan.	Sin.	Tan.	Sin.	Tan.	Sin.	Tan.	M.
	4.68		4.68		4.68		4.68		4.68		
0	5575	5575	5553	5619	5487	5751	5376	5972	5222	6281	0
1	5575	5575	5552	5620	5485	5754	5374	5976	5219	6287	1
2	5575	5575	5551	5622	5484	5757	5372	5981	5216	6293	2
3	5575	5575	5551	5623	5482	5760	5370	5985	5213	6299	3
4	5575	5575	5550	5625	5481	5763	5367	5990	5210	6305	4
5	5575	5575	5549	5627	5479	5766	5365	5994	5207	6311	5
6	5575	5575	5548	5628	5478	5769	5363	5999	5204	6317	6
7	5575	5575	5547	5630	5476	5773	5361	6004	5201	6323	7
8	5574	5576	5547	5632	5475	5776	5358	6008	5198	6329	8
9	5574	5576	5546	5633	5473	5779	5356	6013	5195	6335	9
10	5574	5576	5545	5635	5471	5782	5354	6017	5192	6341	10
11	5574	5576	5544	5637	5470	5785	5351	6022	5189	6348	11
12	5574	5577	5543	5638	5468	5788	5349	6027	5186	6354	12
13	5574	5577	5542	5640	5467	5792	5347	6031	5183	6360	13
14	5574	5577	5541	5642	5465	5795	5344	6036	5180	6366	14
15	5573	5578	5540	5644	5463	5798	5342	6041	5177	6372	15
16	5573	5578	5539	5646	5462	5802	5340	6046	5173	6379	16
17	5573	5578	5539	5648	5460	5805	5337	6051	5170	6385	17
18	5573	5579	5538	5649	5458	5808	5335	6055	5167	6391	18
19	5573	5579	5537	5651	5457	5812	5332	6060	5164	6398	19
20	5572	5580	5536	5653	5455	5815	5330	6065	5161	6404	20
21	5572	5580	5535	5655	5453	5818	5327	6070	5158	6410	21
22	5572	5581	5534	5657	5451	5822	5325	6075	5154	6417	22
23	5572	5581	5533	5659	5450	5825	5322	6080	5151	6423	23
24	5571	5582	5532	5661	5448	5829	5320	6085	5148	6430	24
25	5571	5583	5531	5663	5446	5833	5317	6090	5145	6436	25
26	5571	5583	5530	5665	5444	5836	5315	6095	5141	6443	26
27	5570	5584	5529	5668	5443	5840	5312	6100	5138	6449	27
28	5570	5584	5527	5670	5441	5843	5310	6105	5135	6456	28
29	5570	5585	5526	5672	5439	5847	5307	6110	5132	6462	29
30	5569	5586	5525	5674	5437	5851	5305	6116	5128	6469	30
31	5569	5587	5524	5676	5435	5854	5302	6121	5125	6476	31
32	5569	5587	5523	5679	5433	5858	5300	6126	5122	6482	32
33	5568	5588	5522	5681	5431	5862	5297	6131	5118	6489	33
34	5568	5589	5521	5683	5430	5866	5294	6136	5115	6496	34
35	5567	5590	5520	5685	5428	5869	5292	6142	5112	6503	35
36	5567	5591	5518	5688	5426	5873	5289	6147	5108	6509	36
37	5566	5592	5517	5690	5424	5877	5286	6152	5105	6516	37
38	5566	5593	5516	5693	5422	5881	5284	6158	5101	6523	38
39	5566	5593	5515	5695	5420	5885	5281	6163	5098	6530	39
40	5565	5594	5514	5697	5418	5889	5278	6168	5095	6537	40
41	5565	5595	5512	5700	5416	5893	5276	6174	5091	6544	41
42	5564	5596	5511	5702	5414	5897	5273	6179	5088	6551	42
43	5564	5598	5510	5705	5412	5900	5270	6185	5084	6557	43
44	5563	5599	5509	5707	5410	5905	5268	6190	5081	6564	44
45	5562	5600	5507	5710	5408	5909	5265	6196	5077	6571	45
46	5562	5601	5506	5713	5406	5913	5262	6201	5074	6578	46
47	5561	5602	5505	5715	5404	5917	5259	6207	5070	6585	47
48	5561	5603	5503	5718	5402	5921	5256	6212	5067	6593	48
49	5560	5604	5502	5720	5400	5925	5254	6218	5063	6600	49
50	5560	5605	5501	5723	5398	5929	5251	6224	5060	6607	50
51	5559	5607	5499	5726	5396	5933	5248	6229	5056	6614	51
52	5558	5608	5498	5729	5394	5937	5245	6235	5053	6621	52
53	5558	5609	5497	5731	5392	5942	5242	6241	5049	6628	53
54	5557	5611	5495	5734	5389	5946	5239	6246	5045	6635	54
55	5556	5612	5494	5737	5387	5950	5237	6252	5042	6643	55
56	5556	5613	5492	5740	5385	5955	5234	6258	5038	6650	56
57	5555	5615	5491	5743	5383	5959	5231	6264	5034	6657	57
58	5554	5616	5490	5745	5381	5963	5228	6269	5031	6665	58
59	5554	5618	5488	5748	5379	5968	5225	6275	5027	6672	59
M.	Sin.	Tan.	Sin.	Tan.	Sin.	Tan.	Sin.	Tan.	Sin.	Tan.	M.

APPENDIX

EXPLANATION OF TABLES *

LOGARITHMS AND NATURAL FUNCTIONS

1. **Definition.** — A logarithm of a number is the exponent of the power to which a given number, called the base, must be raised to produce that number; or, in algebraic language, if $a^x = N$, then $\log_a N = x$, which is read "logarithm of N to the base a is equal x."

2. Logarithms facilitate numerical calculations. For multiplying, dividing, raising to a power, or extracting a root, we have the following formulæ, for a proof of which the student is referred to works on algebra:

$$\text{I.}\quad \log A \times B = \log A + \log B.$$

$$\text{II.}\quad \log \frac{A}{B} = \log A - \log B.$$

$$\text{III.}\quad \log A^n = n \log A.$$

$$\text{IV.}\quad \log \sqrt[n]{A} = \frac{1}{n} \log A.$$

3. Logarithms were invented by John Napier,† and first published in 1614. Henry Briggs of England rendered the invention much more useful by employing 10 as the base. Our tables are computed to this base. We cannot here consider the method of computing ‡ logarithms, for we are concerned mainly with the use of the tables. When there can be no uncertainty as to what base is used, it is not necessary to express the base; thus, as 10 is the recognized base, instead of writing $\log_{10} 100 = 2$ we write simply $\log 100 = 2$.

* As Tables XVII, XVIII, XIX, and XX are copied, as elsewhere stated, from Professor Webster Wells's "Six-Place Logarithmic Tables," it is due him to say that this appendix was written by the author, Professor Wells being in no way responsible for this explanation of the tables.

† Baron of Merchiston, Scotland.

‡ The formulæ for this purpose may be found in works on trigonometry and higher algebra.

4. The logarithm of any exact power of the base 10 is a whole number. This follows at once from the definition (Art. 1). The logarithm of any other power of the base is not an exact number, but consists of two parts, a whole number called the *characteristic* and a decimal part called the *mantissa.*

For

$$10^0 = 1, \quad \text{hence } \log 1 = 0$$
$$10^1 = 10, \quad \text{hence } \log 10 = 1$$
$$10^2 = 100, \quad \text{hence } \log 100 = 2$$
$$10^3 = 1000, \quad \text{hence } \log 1000 = 3;$$

and so on.

Also

$$10^{-1} = .1, \quad \text{hence } \log .1 = -1$$
$$10^{-2} = .01, \quad \text{hence } \log .01 = -2$$
$$10^{-3} = .001, \quad \text{hence } \log .001 = -3;$$

and so on.

From the above we see that

the logarithm of a number between 1 and 10 lies between 0 and 1,
the logarithm of a number between 10 and 100 lies between 1 and 2,
the logarithm of a number between 100 and 1000 lies between 2 and 3,
and so on;

and

the logarithm of a number between 1 and .1 lies between 0 and -1,
the logarithm of a number between .1 and .01 lies between -1 and -2,
the logarithm of a number between .01 and .001 lies between -2 and -3,
and so on.

5. The logarithm of a number less than 1 is negative, but it is so written that the mantissa (or decimal part) is always positive. For the number may be regarded as the product of two factors, one of which lies between 1 and 10, and the other is a negative power of 10; for example,

$$.56 = 5.6 \times 10^{-1},$$

and

$$\begin{aligned} \log .56 &= \log 5.6 + \log 10^{-1} \\ &= -1 + \log 5.6 \\ &= -1 + .748188, \text{ which is written} \end{aligned}$$
$$\log .56 = \bar{1}.748188.$$

The minus sign is placed above the characteristic to indicate that the sign belongs to it alone, while the mantissa is positive.

Again,

$$.024 = 10^{-2} \times 2.4.$$
$$\begin{aligned} \therefore \log .024 &= \log 10^{-2} + \log 2.4 \\ &= -2 + .380211 = \bar{2}.380211. \end{aligned}$$

6. From Arts. 4 and 5, we derive the following rules for determining the characteristic of a logarithm:

(*a*) *If the number is greater than 1, the characteristic is positive and numerically one less than the number of figures in the integral part of the number.*

(*b*) *If the number is less than* 1, *the characteristic is negative and numerically one more than the number of zeros before the first significant figure of the decimal.*

Thus, the characteristic of $\log 427.32 = 2$,

the characteristic of $\log 9.7246 = 0$,

the characteristic of $\log .247 = -1$,

the characteristic of $\log .00645 = -3$.

NOTE. — The position of the decimal point affects the characteristic only, the mantissa being the same for the same sequence of figures. For example, the mantissas of 4582076, 45820.76, 458.2076, 4.582076, .0004582076, are alike. See Art. 12.

7. The *co-logarithm* * of a number is the logarithm of the reciprocal of that number, and is obtained by subtracting the logarithm from 0.† To avoid a negative characteristic, it is customary to subtract the logarithm from 10 and take 10 from the result.

Thus, $\log 2 = 0.301030$;

then $\text{colog } 2 = (10 - 0.301030) - 10,$

$= 9.698970 - 10.$

Again, $\log .002 = \bar{3}.301030.$

$\therefore \text{colog } .002 = 12.698970 - 10,$

$= 2.698970.$

The characteristic of a logarithm is always obtained by rule (Art. 6), and is seldom expressed in a table. The mantissa is obtained from the tables, as explained below.

TABLE XVII

8. This table, pages 163 to 178, contains the logarithms of numbers from 1 to 10,000, to six decimal places. The first three figures of the number are given in the column headed "N," the fourth figure being found at the top or bottom of the columns to the right of the letter N. In the last column headed "D" is given the average difference between the successive mantissas in the row in which the difference is found. To make the page more open and thus lessen the strain on the eyes, the first two figures of the six are left out when their omission can cause no mistake. In looking

* Sometimes called the *arithmetical complement* of the logarithm.

† For, $\text{colog } A = \log \frac{1}{A} = \log 1 - \log A = 0 - \log A.$

for a logarithm, if only the last four figures of the mantissa are found, the first two may be obtained from the nearest mantissa above, in the same column, which contains six figures.

9. To find the Logarithm of a Number Less than 100. — We look in the "N" column for 100 times or 10 times the number according as the number is less than 10 or equal to or greater than 10, and take out the mantissa found in the "0" column opposite.

Thus, if the log 2 is required, we find on page 165, in the "0" column opposite 200, the mantissa 301030; the characteristic determined by rule is 0. Hence, $\log 2 = .301030$.

So $\log 42 = 1.623249$, the mantissa being given on page 169 in "0" column, opposite 420.

10. To find the Logarithm of a Number of Three Figures. — Here the mantissa is found in the "0" column opposite the given number.

Thus, page 169, $\log 457 = 2.659916$.

11. To find the Logarithm of a Number of Four Figures. — Here the first three figures are found in the "N" column, the fourth is given at the top, or bottom, of the page, and the mantissa is taken out of the column containing the fourth figure and in the row in which the first three figures of the number are found. Thus,

Page 172,	$\log 5886 = 3.769820$;
Page 173,	$\log 6400 = 3.806180$;
Page 174,	$\log 78.26 = 1.893540$.

12. To find the Logarithm of a Number of Five or More Figures. — We must here use a process called *interpolation.**

Required the logarithm of 43826.

By our rule, we know at once that the characteristic is 4. Now the mantissa of 43826 is the same as the mantissa of 4382.6, and the difference between the mantissa of 4382 and 4382.6 is six-tenths the difference between the mantissas of 4382 and 4383.

From the table, page 169, we have

mantissa of	$4382 = .641672$
mantissa of	$4383 = .641771$
difference	$= .000099$
and .6 of .000099	$= .000059$,

the 4 which would appear in the seventh place being discarded.†

* Interpolation is based on the assumption that between two successive mantissas the change in the mantissa is proportional to the change in the number. While this assumption is not strictly true, it gives a result sufficiently accurate in practice unless the logarithmic function of an angle very near to 0° or 90° is required.

† When the fraction of a unit in such cases is less than .5, it is neglected; if it is .5, or more than .5, it is to be taken as one unit, and the figure in the sixth place increased by 1.

Therefore, adding this to the mantissa of 4382, we have

$$.641672 + .000059 = .641731,$$

and
$$\log 43826 = 4.641731.$$

NOTE. — The difference between the two consecutive mantissas is usually obtained mentally, or else simply taken from the "D" column in the row in which the first three figures of the number are found. It is not necessary, or usual, to write this difference as a decimal, as it is always to be applied to the last figures of the mantissa. In this case, we should say $.6 \times 99 = 59$, and this, added (mentally) to .641672, gives .641731, the mantissa sought.

Required log 675746.

Here, remembering that the mantissa of 6757.46 is the same as the mantissa of 675746, we have, from page 173,

mantissa of 6757 = .829754,

mantissa of 6758 = .829818.

Difference (taken from "D" column) = 64.

Here we take .46 of $64 = 29.44$, which we call 29. Adding 29 to .829754, we have

$$\log 675746 = 5.829783.$$

Required log .00017428.

The mantissa is the same as the mantissa of 1742.8, and is therefore equal to the mantissa of 1742 plus .8 of the difference between the mantissas of 1742 and 1743 (that is, page 165, $.8 \times 249 = 199$).

$$\therefore \log .00017428 = \bar{4}.241247.$$

NOTE. — If the given number contained seven significant figures, then we should have to take so many thousandths of the tabular difference. Thus, page 12,

$$\log 724.6873 = 2.860098 + .873 \times 60 = 2.860150.$$

To find the Antilogarithm, *that is, the number corresponding to a given logarithm.*

13. If the exact mantissa can be found in the table, then the corresponding number is taken out at once, the first three figures being found in the "N" column in the row with the given mantissa, and the fourth figure at the top (bottom) of the column in which the mantissa occurs.

The characteristic determines the position of the decimal point in the antilogarithm, according to the following rules:

If the characteristic is positive, point off one more place than the number denoted by the characteristic.

If the characteristic is negative, the antilogarithm is entirely decimal and the number of zeros immediately after the decimal point is one less than the number denoted by the characteristic.

EXAMPLES:

If $\log x = 2.147676$, find x. On page 164, we find this exact mantissa in the row with 140 (in "N" column) and in the column headed 5. Hence, the antilogarithm is 140.5, the characteristic, 2, determining the position of the decimal point.

Again, if $\log x = \bar{4}.329398$, then, page 165, $x = .0002135$, for the mantissa is found in the row with 213 and in column "5," and the characteristic shows that there are three zeros before the first significant figure of the decimal.

14. If the mantissa of the given logarithm cannot be found in the table, then we must interpolate.

Given $\log x = 2.306530$, to find x.

Here the mantissa lies between .306425 and .306639, which are two consecutive mantissas given in the table, page 165. Hence, the antilogarithm lies between 202.5 and 202.6. The difference between the two consecutive mantissas is $.306639 - .306425 = .000214$, or, as we say, 214. [Here the "D" column gives 215, which would give practically the same result.] The difference between the given mantissa, .306530, and the smaller of these, .306425, is 105. Now, we assume* that if a difference of 214 in the mantissa makes a difference of 1 in the fourth place of the antilogarithm, then a difference of 105 in the mantissa will make a difference of $\frac{105}{214}$ of 1 in the antilogarithm.

Hence, $\frac{105}{214}$ of $1 = 0.4907$ is to be annexed to 2025, making 20254907.

$$\therefore\ x = 202.54907.$$

NOTE. — In practice, the decimal here would probably not have been carried beyond the third place.

Again, given $\log x = \bar{3}.837241$, find x.

Here, page 173, the mantissa lies between .837210 and .837273, and hence (ignoring the characteristic for the moment) the antilogarithm lies between 6874 and 6875. The tabular difference is 63, and the difference between the given mantissa .837241 and .837210 is 31.

Hence, we annex to 6874

$$\tfrac{31}{63} \text{ of } 1 = .49.$$

$$\therefore\ x = .00687449.$$

As a further illustration of the application of logarithms and the use of the tables, we give in the next article a few examples.

15. EXAMPLES.

(1) Find the value of x, if $x = 82473 \times .0723$.

Here (Art. 2) $\log x = \log 82473 + \log .0723$, and the work is conveniently arranged as follows:

* Footnote, page 246.

Page 176,	$\log 82473 = 4.916312$	
Page 174,	$\log .0723 = \bar{2}.859138$	
Art. 2,	$\therefore \log x = 3.775450$	
Page 172,	$\therefore x = 5962.794.$	

NOTE.—Multiplying 82,473 by .0723 by the ordinary process, we get $x = 5962.7979$, which shows that, by employing logarithms, we get a result differing from the true product by .0039. The result, then, as might be inferred, is an approximate one; but logarithms are only used where such slight discrepancies make no practical error.

(2) Find x, if $x = 472068 \div 34.2$.

Here $\log x = \log 472068 - \log 34.2$.

Page 8,	$\log 472068 = 5.674005$
Page 6,	$\log 34.2 = 1.534026$
Subtracting,	$\log x = 4.139979$
	$\therefore x = 13803.17.$

NOTE.—Instead of subtracting the logarithm, we may add the cologarithm of 34.2; thus (Art. 7):

$$\begin{aligned} \log 472068 &= 5.674005 \\ \text{colog } 34.2 &= 8.465974 - 10 \\ \text{Adding,}\quad \log x &= 4.139979 \end{aligned}$$

(3) Find x, if $x = \dfrac{384 \times .0024 \times 782.94}{.07824 \times 47}$.

$$\begin{aligned} \text{Here}\quad \log 384 &= 2.584331 \\ \log .0024 &= \bar{3}.380211 \\ \log 782.94 &= 2.893728 \\ \text{colog } .07824 &= 11.106571 - 10 \\ \text{colog } 47 &= 8.327902 - 10 \\ \therefore\text{, adding,}\quad \log x &= 22.292743 - 20 \\ \text{or}\quad \log x &= 2.292743. \\ \therefore x &= 196.219. \end{aligned}$$

NOTE.—A *negative* number has no common logarithm. If such numbers occur in practice, they are treated as positive numbers, and the *sign* of the result is determined irrespective of the logarithmic work. For example, if the value of $-24782 \times +78.702$ is to be determined by logarithms, we treat both numbers as positive in getting their logarithms, and we give the result the *minus* sign, *because* the product of a + quantity by a − quantity is negative.

TABLE XVIII

16. Table XVIII gives the logarithmic sines, cosines, tangents, and cotangents from 0° to 90°. The formulæ

$$\sin (90° - A) = \cos A,\ \cos (90° - A) = \sin A,$$
$$\tan (90° - A) = \cot A,\ \cot (90° - A) = \tan A,$$

are used to reduce the size of such a table one-half, as will now appear. At the top of the pages the degree numbers run from 0° to 44°, while at the bottom, they run in reverse order from 45° to 90°; and at the bottom the cosine, sine, cotangent, and tangent columns correspond respectively to the sine, cosine, tangent, and cotangent at the top. If the angle is less than 45°, the function is read at the top of the page; if it is greater than 45°, the function is found at the bottom of the page. The minutes for the functions at the top are found in the first column and run *down*, while the minutes for the functions at the bottom are given in the last column and run *up*. If seconds occur, interpolation is used.

Where the characteristic would be negative, **10** is added to make it positive, and this positive characteristic is given in the table.

17. *To find the logarithmic function when the angle contains degrees and minutes and no seconds.*

Here the logarithmic function is taken out at once from the table; for example:

Page 188,	$\log \sin 8° 20' = 9.161164.$
Page 181,	$\log \cos 88° 10' = 8.505045.$
Page 197,	$\log \tan 17° 53' = 9.508759.$
Page 221,	$\log \cot 41° 14' = 0.057267.$

Caution. — When the angle is greater than 45°, read the function at the *bottom* of the page, and read the minutes on the *right-hand side* of the page.

18. *To find the logarithmic function when the angle contains seconds.*

Here we must interpolate (see footnote, page 246). To assist in this interpolation, the difference in the last figures of the logarithm for 1″ is given.* As the tangent and cotangent vary alike, one column of differences is sufficient for both, and this, in our table, is put between the tangent and cotangent columns.

(1) To find $\log \sin 20° 34' 18''$.

Here, page 200, $\log \sin 20° 34' = 9.545674$, as found in the sine column opposite 34 minutes.

Difference for $1'' = 5.62.$

$\therefore$ difference for $18'' = 18 \times 5.62 = 101,$

and $9.545674 + 101 = 9.545775,$

or $\log \sin 20° 34' 18'' = 9.545775.$

* It will be noticed that these differences do not stand in the same horizontal row with the logarithms, but opposite the intervals between consecutive logarithms. With the degrees at the *top* of the page, the difference next *below* should be taken; with the degrees at the *bottom* of the page, the difference next *above*.

(2) To find log cos $41° 10' 47''$.

$$\begin{aligned} &\text{Page 221,} && \log\cos 41° 10' = 9.876678 \\ &\text{Difference for} && 47'' = 47 \times 1.83 = \quad 86 \\ &\therefore\text{, subtracting,} && \log\cos 41° 10' 47'' = 9.876592 \end{aligned}$$

Here the difference for $47''$ is subtracted, for the cosine decreases as the angle increases.

NOTE.—Observe that the sine and tangent increase, while the cosine and cotangent decrease, as the angle increases.

(3) To find log tan $54° 38' 52''$.

As the angle is greater than $45°$, we read from the botton, page 215.

$$\begin{aligned} && \log\tan 54° 38' = .148871 \\ && \text{Difference} = 52 \times 4.47 = \quad 232 \\ &\therefore\text{, adding,} && \log\tan 54° 38' 52'' = .149103 \end{aligned}$$

(4) To find the log cot $11° 52' 44''$.

$$\begin{aligned} &\text{Page 191,} && \log\cot 11° 52' = .677521 \\ && &\text{Differnec} = 44 \times 10.45 = \quad 460 \\ &\therefore\text{, subtracting,} && \log\cot 11° 52' 44'' = .677061 \end{aligned}$$

To find the angle when the logarithmic function is given.

19. If the exact logarithmic function is found in the table, then the angle may be at once written down by taking the degrees from the top or bottom, as the case may be, and the minutes from the minute column on the left or right of the page.

$$\begin{aligned} &\text{Thus, if} && \log\sin A = 9.303979, \\ &\text{then, page 191,} && A = 11° 37'. \\ &\text{If} && \log\cot B = 9.318697, \\ &\text{then, page 191,} && B = 78° 14'. \end{aligned}$$

20. If the exact logarithmic function cannot be found in the table, then the angle is found by interpolation, as in the following examples:

(1) Given $\log\sin A = 9.476721$, to find A.

Here (page 197) the mantissa is contained between the mantissas corresponding to $17° 26'$ and $17° 27'$; hence, evidently, $A = 17° 26' +$ some seconds. Now,

$$\begin{aligned} &\text{Mantissa for} && \log\sin 17° 26' = .476536 \\ &\text{Mantissa for} && \log\sin A = .476721 \\ && &\text{Difference} = \quad 185 \end{aligned}$$

In the difference column we find that the logarithmic sines at this point increase at the rate of 6.70 per second. Hence, a difference of 185 would correspond to $\frac{185}{6.7} = 28''$, to the nearest second.

$$\therefore A = 17° 26' 28''.$$

(2) Given $\log \cos A = 9.720238$, to find A.

We see (page 211) that the given logarithm lies between the logarithmic cosine of 58° 19′ and 58° 20′.

$$\begin{aligned} \log \cos 58^\circ\, 19' &= 9.720345 \\ \log \cos A &= \underline{9.720238} \\ \text{Difference} &= \qquad 107 \\ D \text{ for } 1'' &= 3.42. \end{aligned}$$

$\therefore$ the number of seconds to be added $= \dfrac{107}{3.42} = 31$, and therefore $A = 58^\circ\, 19'\, 31''$.

(3) Given $\log \tan A = 9.990201$, to find A.

Here (page 224) the given logarithm lies between 9.990145 and 9.990398, and therefore the angle lies between 44° 21′ and 44° 22′.

$$\begin{aligned} \log \tan 44^\circ\, 21' &= 9.990145 \\ \log \tan A &= \underline{9.990201} \\ \text{Difference} &= \qquad 56 \\ \text{Seconds to be added} &= \frac{56}{4.22} = 13. \\ \therefore\ A &= 44^\circ\, 21'\, 13''. \end{aligned}$$

NOTE.—In practice, the difference, such as 56 in Ex. 3, is usually obtained mentally, and thus the work is greatly expedited.

(4) Given $\log \cot A = 0.327941$, to find A.

Here the angle evidently (page 205) lies between 25° 10′ and 25° 11′.

Difference between $\log \cot 25^\circ\, 10'$ and $\log \cot A$ is 96, and $D = 5.47$.

$$96 \div 5.47 = 18'', \text{ to be added.}$$

$$\therefore\ A = 25^\circ\, 10'\, 18''.$$

21. Secant and Cosecant.—If the logarithmic secant and logarithmic cosecant are required, we express these functions in terms of the cosine and sine by the formulæ:

$$\sec x = \frac{1}{\cos x},\quad \operatorname{cosec} x = \frac{1}{\sin x},$$

whence

$$\log \sec x = \operatorname{colog} \cos x.$$

$$\log \operatorname{cosec} x = \operatorname{colog} \sin x.$$

22. Angles Greater than 90°.

Angles in the second quadrant are reduced to acute angles by means of the formulæ:

$$\sin(180^\circ - x) = \sin x;\quad \tan(180^\circ - x) = -\tan x;$$

$$\cos(180^\circ - x) = -\cos x;\quad \cot(180^\circ - x) = -\cot x.$$

Angles greater than 180° are also readily reduced to acute angles by the proper trigonometric formulæ.

NOTE.—*Negative functions.* Strictly speaking, a negative angle or a negative function has no logarithm. When they occur, we treat them as positive as far as the logarithmic work is concerned. Compare note under Ex. 3, Art. 15. Also see Ex. 1, Art. 23. To call attention to the fact that the function is negative, the letter "n" is sometimes written after the logarithmic function; thus,

since $\cos 120° 40' = -\cos(180° - 120° 40') = -\cos 59° 20'$,

$$\log \cos 120° 40' = 9.707606_n - 10.$$

23. EXAMPLES.

(1) If $x = 123.8 \cos 120° 40'$, find x.

$$\begin{aligned} \log 123.8 &= 2.092721 \\ \log \cos 120° 40' &= \underline{9.707606_n - 10} \\ \therefore\ \log x &= 1.800327_n \\ \therefore\ x &= -63.143. \end{aligned}$$

(2) If $\sin A = \dfrac{40.36 \sin 41° 10' 36''}{124.32}$, find A.

$$\begin{aligned} \log 40.36 &= 1.605951 \\ \log \sin 41° 10' 36'' &= 9.818478 - 10 \\ \text{colog}\ 124.32 &= \underline{7.905459 - 10} \\ \therefore\ \log \sin A &= 9.329888 - 10 \\ \therefore\ A &= 12° 20' 30''. \end{aligned}$$

(3) If $x = \dfrac{4721.6 \times \tan 0° 40' 24''}{348 \times \cot 20° 52'}$, find x.

$$\begin{aligned} \log 4721.6 &= 3.674089 \\ {}^{*}\log \tan 0° 40' 24'' &= 8.070096 - 10 \\ \text{colog}\ 348 &= 7.458421 - 10 \\ \text{colog}\ \cot 20° 52' &= \underline{9.581149 - 10} \\ \log x &= 28.783755 - 30 \\ &= \bar{2}.783755. \end{aligned}$$

Whence $x = 0.06078.$

TABLE XIX

24. This table speaks for itself, and detailed explanations seem unnecessary. Here the values of the natural functions for each minute from 0° to 90° are given to five decimal places.

If it is desired to have the values for fractions of a minute, we interpolate just as in the logarithmic tables, only in this table the tabular dif-

* The logarithmic function of this small angle could be found with a greater degree of accuracy by the use of Table XX. See Art. 27.

ference for 1″ is not given, but must be computed. It is one-sixtieth of the difference between two consecutive values of the function.

For example, let the natural sine of 20° 34′ 37″ be required.

$$\begin{array}{lrl} \text{Page 232,} & \sin 20° 34' = & .35130 \\ & \sin 20° 35' = & \underline{.35157} \\ & \text{Difference for } 60'' = & \quad\ 27 \\ & \therefore \text{ Difference for } 37'' = & \tfrac{37}{60} \times 27 = 17. \end{array}$$

$$\therefore \sin 20° 34' 37'' = .35130 + .00017 = .35147.$$

25. Table XIX as a Traverse Table. — As noted in Art. 151, that part of this table in which the sines and cosines are given may be used as a *traverse table*. *For the distance unity*, the *sine* gives the "*departure*" of a course, the *cosine*, its "*latitude*."

EXAMPLES.

(1) Required the departure and latitude of a course whose bearing is N. 21° 40′ E. and whose length is 4 chains. On page 201, we find

$$\sin 21° 40' = .36921 = \text{departure for distance 1.}$$

$$\cos 21° 40' = .92935 = \text{latitude for distance 1.}$$

$$\therefore \text{ Departure of given course} = 4 \times .36921 = 1.48.$$

$$\text{Latitude of given course} = 4 \times .92935 = 3.72.$$

(2) Required the latitude and departure of a course AB, of length 21.36 chains, whose bearing is S. 82° 20′ W.

Here, page 228,

$$\sin 82° 20' = .99106 = \text{departure for distance 1.}$$

$$\cos 82° 20' = .13341 = \text{latitude for distance 1.}$$

$$\therefore \text{ Departure of } AB = 21.36 \times .99106 = 21.17.$$

$$\text{Latitude of } AB = 21.36 \times .13341 = 2.85.$$

TABLE XX

AUXILIARY TABLE FOR SMALL ANGLES

26. This table gives under the heads "Sin" and "Tan," respectively, the values of the two expressions.

$10 + \log \sin x - \log x$ and $10 + \log \tan x - \log x$, x being expressed in seconds for each minute from 0° to 4° 59′.

The object of the table is to find the logarithmic sines and tangents of angles between 0° and 5° (and therefore of cosines and cotangents between 90° and 85°) to a greater degree of accuracy than is possible from Table XVIII. Within the same limits, it may of course be used in obtaining the angle from a given logarithmic function.

27. *To find the logarithmic sine or tangent of an angle between* $0°$ *and* $5°$.

Find from the auxiliary table the logarithm corresponding to the given function, add to the result the logarithm of the number of seconds in the angle, and write -10 *after the mantissa.*

EXAMPLE. — Find log sin $2° 35' 26''$.

The logarithms (from Table XX) corresponding to sin $2° 35'$ and sin $2° 36'$ are 4.685428 and 4.685426, and their difference is 2.

Hence, $\frac{26}{60}$ of $2 = 1$, nearly, is to be subtracted from 4.685428, giving 4.685427.

Now $2° 35' 26'' = 9326''$.

$$\begin{array}{rl} & 4.685427 - 10 \\ \log 9326 = & \underline{3.969695} \\ \therefore \log \sin 2° 35' 26'' = & 8.655122 - 10 \end{array}$$

The result by Table XVIII is $8.655121 - 10$.

28. *To find the angle corresponding to a given logarithmic sine or tangent when between* $0°$ *and* $5°$.

Find from Table XVIII the angle corresponding to the given logarithm, to the nearest second.

Take from Table XX the logarithm corresponding to this angle.

Subtract the result from the given logarithm, and find the number corresponding to the difference, giving the required angle in seconds.

EXAMPLE. — Find the angle whose log tan $= 8.021348$.

From Table XVIII, the angle corresponding is $0° 36' 7''$ to the nearest second.

From Table XX, the logarithm corresponding to $0° 36' 7''$ is

$$4.685591 - 10.$$

$$\begin{array}{l} 8.021348 - 10 \\ \underline{4.685591 - 10} \\ 3.335757 \end{array}$$

Number corresponding to this $= 2166.49$.

$\therefore$ required angle $= 2166.49'' = 0° 36' 6.49''$.

NOTE. — Remembering that the tangent and cotangent are reciprocals, we see that this table may readily serve to determine the cotangent of an angle between $0°$ and $5°$ and the tangent of an angle between $85°$ and $90°$, or the angle corresponding in the same cases.

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